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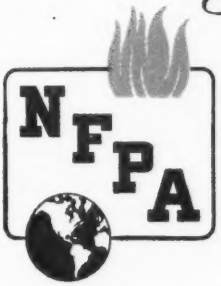
NATIONAL FIRE PROTECTION ASSOCIATION

Quarterly



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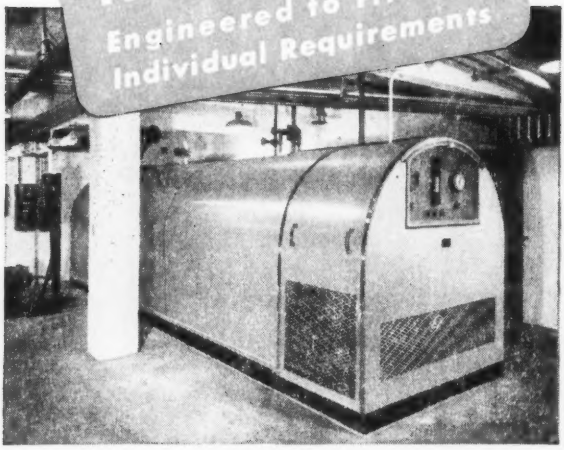

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of the

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Accounts of fires appearing in the Quarterly are copies of or extracts from reports forwarded to the Association. This Association, as a body, is not responsible for the statements or opinions of any of its members.

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This fire at the Treasure Island Navy Base, San Francisco Bay, April 10, 1947, destroyed buildings having a ground area of over 7 acres, all of wooden construction, without automatic sprinklers. Three fire walls did not extend through the roof, and fire doors were tied open. After delayed discovery, 54 fire companies from San Francisco and Oakland, plus 12 pieces of Navy fire apparatus, used 92 hose lines, but were powerless to prevent total loss.

The Quarterly

Vol. 41 July, 1947 No. 1

Fire Prevention Activities of U. S. Chamber

By Arch N. Booth,
Manager, Chamber of Commerce of the United States.

Man's early discovery that fire, generated by a lightning bolt, could be used for human comfort, started the human race on its way to civilized living. Man soon discovered, too, that fire has its destructive as well as its constructive uses. Our present problem is how to checkmate this modern Moloch, which devours our people and devastates our property.

For more than twenty-five years, the Chamber of Commerce of the United States has taken an active part in promoting fire prevention in the cities, the towns and the countryside of America. The National Conference of Governors twenty-five years ago took steps to enlist the support of local business leaders in a nation-wide fire prevention effort.

Do you remember the situation of that time? Many will recall that following the close of World War I, fire losses throughout the country were mounting rapidly. The rise was comparable to that which has taken place in the last several years and, by 1922, had passed the $500 million mark.

The governors of the various states, the mayors, the state fire marshals, the fire chiefs, and other state and city officials were alarmed. What could be done about it?

The Conference of Governors studied preventive measures. But in all of their plans two basic weaknesses stood out. First was the rapid turnover in the official life of public officials. Second was the difficulty of obtaining general public support for the needed far-reaching measures, such as the amendments to building codes, the financing of increased fire fighting facilities, the extension of fire prevention education, and other projects.

After careful study and consideration of what could be done, the Governors' Conference asked the president of the U. S. Chamber of Commerce to call a meeting of all national organizations which had a direct interest in fire prevention work and were willing to join with business men in implementing a program. The National Chamber was asked to try to persuade every local chamber of commerce to set up a permanent fire prevention committee to carry out a year-round campaign to reduce fire losses.

This article has been abstracted from an address by Mr. Booth, presented at the President's Conference on Fire Prevention, Washington, D. C., May 7, 1947.

all of wooden construction, without automatic sprinklers. Three fire walls did not extend through the roof, and fire doors were tied open. After delayed discovery, 54 fire companies from San Francisco and Oakland, plus 12 pieces of Navy fire apparatus, used 92 hose lines, but were powerless to prevent total loss.

A new organization was set up. Thirty-six national organizations joined with the National Chamber in forming the National Fire Waste Council. Members of the National Fire Protection Association have over the years taken an active part in the Fire Waste Council, and the cooperation of the NFPA has contributed greatly to the success of this activity.

The National Chamber does not endeavor to originate technical knowledge or to establish standards of fire safety. Those functions are supplied by its cooperating organizations which are joined with it in the National Fire Waste Council. The Chamber's job is an organizing, stimulating job, to put this vast store of technical information into use.

The business men's organization in each community is the local chamber of commerce. In the local chambers throughout the country the business men concentrate their interest in broad projects for the good of the community. Fire prevention is an important one of these.

More than 2,100 local chambers of commerce are banded together in the Chamber of Commerce of the United States. It was to these local chambers, therefore, that the National Chamber turned in 1922 to put into effect the plans started by the Governors' Conference.

Twenty-five years is a long time in a rapidly growing country. Let's see what's happened during that time:

First of all, the population of the United States grew from 109,000,000 to 142,656,000.

Secondly, the number of cities having more than 50,000 population grew from 144 to well over 200.

Third, the cities having more than 100,000 population grew from 68 to well over 100.

During this period the number of local chambers in the membership of the United States Chamber more than doubled.

This is only a bird's-eye view of what has happened, but it illustrates how the problem of fire prevention has grown as the country has grown.

Fire prevention is not a theoretical idea. On the contrary, it is intensely practical. The experience of community after community demonstrates that the application of certain well-established techniques will sharply reduce the number and severity of fires.

The cooperation of municipal authorities—particularly fire department officials—is, of course, a prime requisite. But in my experience that has been the easiest part of the job. There are good public officials and bad ones in this country. The good ones are cooperative, responsible, dependable, and easy to work with because of their deep sense of public responsibility. There have been some woefully bad examples of the handling of public responsibility with respect to the preventing of fires. There is only one way to handle public officials who are faithless to their trust; namely, get rid of them — and rapidly.

More than 1,300 of these local chambers of commerce have fire prevention committees and are carrying out year-round fire prevention programs. As a further stimulus, as well as to encourage and reward meritorious effort on the part of local chamber committees, the National Fire Waste Council conducts an annual Inter-Chamber Fire Waste Contest.

At the 1947 annual meeting of the United States Chamber, awards were made to the winners in last year's contest. The winners were Chicago, Ill.; Cincinnati, Ohio; Tulsa, Oklahoma; Newton, Massachusetts; Mansfield, Ohio; and Beatrice, Nebraska, The grand award for the best

all-year-round local fire prevention program put on by any city was won by Mansfield, Ohio.

I would like to point out that Mansfield, Ohio, reduced its fire losses from $4.00 for each resident in Mansfield to about 80¢ per capita. This reduction was made by business men and city officials working together in the Chamber of Commerce.

The improvement of building codes and their administration is one fire prevention field in which the National Chamber has been active. The control of building construction to protect the public safety is traditionally a local function. It is amazing how many different paths have been followed by municipal officials in attempting to reach a common goal. A building code is a complex instrument, and the amount of time and expense involved in revising it has a distinct tendency to discourage its frequent modernization.

Efforts to promote greater uniformity and flexibility among building codes have been carried on for many years. Progress has been made, but much still remains to be done. Last November the National Chamber was host to a meeting of the Construction Industry Advisory Council, made up of over a hundred national trade and professional organizations with a direct interest in construction. The discussion at that meeting disclosed that any attempt to evolve a single model code applicable and acceptable to all parts of the country is difficult.

Nevertheless, we believe that the effort to bring about more uniformity will get results and the National Chamber now has a continuing committee working along these lines.

After 25 years of the National Chamber's fire prevention activities, the results in individual cities where a conscientious effort has been put forth have been most encouraging. It proves to us quite conclusively that *where public interest is aroused* and *where a definite program is carried out* under *competent leadership* and *backed up by broad public support,* the *number of fires can be reduced.*

We in the Chamber of Commerce of the United States are heartened by the interest which the President of the United States has shown in this critical national problem. It is my understanding that the President's Conference is not to create any new organization, or to try to bring the existing ones under control of the federal government, but rather to assist them to get better results. The National Chamber and the National Fire Waste Council will continue, in fact will give renewed impetus to, their efforts in this direction.

Fires, like certain diseases that plague the human race, can never be entirely prevented. But that does not mean that we are to accept them with complacency. We must fight them as Churchill said England would fight the dictator enemies—wherever they appear and as long as they persist.

Meetings of Board of Directors

Chicago, Monday, May 26, 1947.

Present.

George W. Elliott, chairman
C. W. Pierce, president
John L. Wilds, vice-president
Hovey T. Freeman, secretary-treasurer
Richard E. Vernor, past president
D. J. Price, past president

Eugene Arms	Russell Grinnell
M. S. Blake	A. J. Mullaney
A. L. Brown	J. A. Neale
H. R. Brown	H. E. Newell
Loren S. Bush	A. H. S. Stead
A. L. Cobb	John Strohm
Jack Curtis	

Percy Bugbee, general manager.

Business Transacted.

1. The report of the chairman of the Board to the annual meeting was approved.

2. The report of the treasurer to the annual meeting was approved.

3. The report of the special Board Committee on Branch Circuit Protection as printed in the *Advance Reports* was approved and Chairman Hylton R. Brown was authorized to present the report at the annual meeting as a report of progress and as representing the views of the Board on the subject matter covered in the report. The special committee was continued.

4. It was tentatively decided to select Washington, D. C., as the place of the 1948 annual meeting and the dates, May 10-13, 1948. Further details in connection with arrangements were left in the hands of the Advisory Committee with power.

5. The following committee appointments were approved:

Committee on Flammable Liquids — R. T. Henderson, Ohio Petroleum Marketers Assn.

Committee on Gases — E. O. Mattocks, F. L. Newcomb, representing American Petroleum Institute.

6. It was voted to hold the next meeting of the Board in Boston on June 30, 1947.

Boston, Monday, June 30, 1947.

Present.

George W. Elliott, chairman
Curtis W. Pierce, president
Hovey T. Freeman, secretary-treasurer
Richard E. Vernor, past president

M. S. Blake	J. A. Neale
A. L. Brown	H. E. Newell
Hylton R. Brown	W. A. Ross
A. L. Cobb	A. H. S. Stead
R. D. MacDaniel	

Percy Bugbee, general manager, Robert S. Moulton, technical secretary, Horatio Bond, chief engineer, Charles S. Morgan, engineer, James K. McElroy, engineer, George H. Tryon, III, engineer.

Business Transacted.

1. In accordance with the vote of the annual meeting, the following officers were elected: President, Curtis W. Pierce; vice-president, Earl O. Shreve; vice-president, John L. Wilds; secretary-treasurer, Hovey T. Freeman; chairman, Board of Directors, George W. Elliott.

2. The Advisory Committee for 1947-48 was appointed as follows: George W. Elliott, chairman, Hovey T. Freeman, Curtis W. Pierce, Earl O. Shreve, John L. Wilds.

3. A. H. S. Stead and John W. Strohm were elected to complete the personnel of the Nominating Committee for 1948.

4. It was voted to confirm the holding of the 52nd annual meeting of the Association in Washington, May 10-13, 1948, and

the general manager was authorized to proceed with the usual arrangements.

5. It was voted tentatively to hold the 1949 annual meeting of the Association in San Francisco the week of May 16, 1949, subject to further action by the Board in 1948.

6. The president, the chairman of the Board, and the general manager were appointed as a Program Committee for the 1948 annual meeting with power to add members from Washington to the committee.

7. The budget for 1947-48 as submitted by the Finance Committee was approved. The staff was authorized to institute all practical economies in printing expenses and related features of service to members.

8. President Pierce's proposals for increased financial support as referred to the Board by action of the 1947 annual meeting were discussed and referred to the Committtee on Long Range Planning for further consideration, in consultation with the treasurer, and report to the Board. The chairman was authorized to reorganize the Committee on Long Range Planning to constitute it for effective consideration of this and other important policy matters affecting the continued welfare of the Association.

9. Chief Engineer Bond reported on the continuing activities of the President's Conference on Fire Prevention, and after discussion it was voted to authorize the staff to continue to cooperate as far as possible in advancing the objectives of the President's Conference. It was further voted to invite President Truman to use the facilities of the NFPA annual meeting in 1948 as a medium for reporting on the fire prevention accomplishments flowing from the 1947 Conference.

10. In accordance with the recommendations of the Committee on Technical Committee Procedure, it was voted to:

(a) Adopt in principle the following new organization to supersede the present Electrical Committee, and authorize the Committee on Technical Committee Procedure to proceed with the details of organization, in consultation with the chairman of the Electrical Committee, subject to confirmation by the Board at its next meeting:

Create an Electrical Section of the Association to include the entire present membership of the Electrical Committee and other members of the Association sufficiently interested to participate, this section to operate under the general rules of procedure established for all NFPA sections, to provide a forum for discussion of proposed Electrical Code changes but to have no voting power on the National Electrical Code.

Reorganize the present Article Committees of the Electrical Committee to give them a greater degree of authority and responsibility in respect to Code changes, such committees to submit their reports to the Section for discussion and comment, and to the governing committee or council for action.

The Board to appoint a small governing committee or council to have voting power on Code changes, to control the organization of the Article Committees, and in general to act as a policy and correlating committee.

Continue the present procedure of submitting Code changes to the NFPA annual meeting for final adoption, and transmitting new editions of the Code to the American Standards Association for approval.

(b) Create a technical Committee on Wearing Apparel, to deal with matters pertaining to the combustibility of clothing and its component materials, with particular reference to personal safety and public regulations in the interest of personal safety, and to act as a point of contact with U. S. government agencies and other organizations concerned with this subject. Authorize the Committee on Technical Committee Procedure to proceed with the appointment of the personnel and the preparation of a scope statement, subject to confirmation by the Board at its next meeting.

(c) Discharge the present Committees on Building Construction and on Con-

struction Operations. Create a new Committee on Building Construction to have the functions of both present committees. Authorize the Committee on Technical Committee Procedure to proceed with the appointment of the personnel and the preparation of a scope statement, subject to confirmation by the Board at its next meeting.

(d) Revise the scope statement of the Committee on Protection of Openings in Walls and Partitions to read as follows:

> Installation and maintenance of fire doors, windows, shutters and other equipment, to restrict the spread of fire, including arrangements for automatic operation in case of fire. Includes installations to protect buildings against external fire and to restrict spread of fire within buildings.

(e) Create a Committee on Dehydrators and Driers to develop standards for grain driers, alfalfa and hay driers, dehydrators and similar equipment, but not to cover industrial equipment of types coming within the jurisdiction of the Committee on Ovens and Furnaces. Authorize the Committee on Technical Committee Procedure to proceed with the appointment of the personnel and the preparation of a scope statement, subject to confirmation by the Board at its next meeting. Request the Committee on Technical Procedure to consider the possible need for committee attention to the hazards of wallboard and wallpaper driers, and the assignment of committee jurisdiction therefor.

(f) Create a Committee on Research with the following scope statement:

> To promote research in fire prevention and fire protection, encourage the interchange of information between research organizations, advise NFPA technical committees and others on request as to research projects, and to report to the Association on such activities.

Authorize the Committee on Technical Committee Procedure to proceed with the appointment of the personnel, including representation from leading organizations now engaged in fire protection research, subject to confirmation by the Board at its next meeting.

11. Proposed revisions in the Standard for Grandstands, Tents and Other Places of Outdoor Assembly submitted for adoption by the Committee on Places of Outdoor Assembly in accordance with the action at the 1947 annual meeting were discussed and referred back to the committee for clarification of certain details and resubmittal to the Board by letter ballot.

12. In accordance with the action of the annual meeting, revised Regulations Governing the Control of Gas Hazards on Vessels to be Repaired, submitted by the Marine Section to supersede Appendix A of the Regulations on Marine Fire Hazards, were adopted with authority to the NFPA office to make editorial changes in numbering.

13. On recommendation of the Committee on Gases, and in accordance with the action of the 1947 annual meeting, it was voted to revise the 1947 edition of the Standards for Liquefied Petroleum Gases, paragraph B.9(b), first section to read as follows:

> (b) Container safety relief valves shall be set to start to discharge as follows, with relation to the design working pressure of the container;

14. The Executive Office was authorized to submit to the Board for approval by letter ballot revisions of other standards which the Board was authorized to consider by action of the annual meeting at such time as committee recommendations may be received by the Executive Office.

15. It was voted to confirm technical committee appointments in accordance with the list submitted with the agenda for the meeting, to authorize the Committee on Technical Committee Procedure to make further technical committee appointments prior to the publication of the 1947 Year Book, subject to confirmation by the Board at its next meeting, and to reappoint for the committee year 1947-48 all members of technical committees not otherwise mentioned. (The personnel of committees will appear in the 1947-1948 Year Book.)

16. A communication from the National Automatic Sprinkler and Fire Control Association relative to the fire safety of hotels was discussed and referred to the Committee on Safety to Life and to the Fire Marshals' Section.

New Method of Protecting Conveyor Openings

By Norman J. Thompson,
Director, Factory Mutual Laboratories.

Modern industry has demanded increased use of high speed production practices involving fabricating and assembly operations on conveyor lines; and for these lines it has become increasingly necessary to cut openings in fire walls and through floors to accommodate continuous conveyors. On account of the nature of objects passing along on the conveyor line, it is often impractical to obtain effective fire protection of these openings by means of the usual fire doors or shutters. The problem has been given intensive study within the last three or four years to see if some protection method could be developed which might prove more effective than the discharge from automatic sprinklers. These are generally located under or immediately adjacent to the opening, installing one or two sprinkler heads for every four or five feet of width.

Experimental work by the Factory Mutual Laboratories in using water spray nozzles on fires had shown much higher than expected air movements from ordinary commercial spray nozzles of the high velocity solid cone type of discharge. For example, at 50 p.s.i. nozzle pressure, nozzles of 5/16-in. diameter orifice size would produce a free air movement of around the order of 8,000 cu. ft. per min., 3/8-in. nozzles around 10,000 cu. ft. per min., 1/2-in. nozzles around 13,000 cu. ft. per min., and 3/4-in. nozzles about 18,000 cu. ft. per min. Considering these high air flow rates, it would be expected that these nozzles could exert an appreciable effect in opposing counter air movement.

Principle of the Method.

It was our idea that it might be possible to prevent fire from passing through conveyor openings by taking advantage of the pressure effect of water spray and the cooling action simultaneously obtainable. In order to prevent passage of fire from one room to another through an opening in a fire wall, it was obvious that there would be a definite advantage in locating the nozzle or nozzles so that the water spray would cover completely the opening and discharge in a direction to oppose the passage of hot gases from the fire zone into the area to be protected. Such a nozzle arrangement is shown in Fig. 1. Since the nozzles themselves must be located so as to permit free travel of solid objects on the conveyor, it is necessary that the nozzles be offset and arranged to discharge at the plane of the conveyor opening at some angle varying from normal.

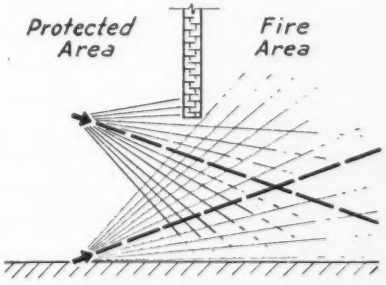


Fig. 1.

This article was presented as an address at the fifty-first annual meeting of the National Fire Protection Association, Chicago, May 26-29, 1947.

Counterdraft Effect.

One of our earliest test series was run to determine what back pressure would be created by nozzles of various types and sizes, and at varying nozzle pressures. We soon learned that the individual spray characteristics of nozzles were of less importance than the rate of water discharge. While the air compressing action of the stream of spray depends not only on the velocity but also on the combined frontal area of all the individual drops, it is true that the smaller the size of the individual drops the sooner they lose their initial velocity. Therefore, except for very small openings, where the nozzles could be placed only a short distance away, it was found necessary to employ larger nozzles giving coarser drops which would maintain their velocities without serious loss for distances of from 6 to 10 ft.

Fig. 2 gives a fair idea of what can be obtained in the way of back pressure at an opening with half-inch orifice spray nozzles of about 60° discharge angle. At low nozzle pressures and correspondingly low rates of water discharge the nozzles are very inefficient in creating pressure. At the higher discharge rates the curve is almost a straight line, due to higher drop velocity and in some degree to the greater surface area of smaller drops. With this nozzle it requires about 55 p.s.i. nozzle pressure to produce a counterdraft effect of 0.10 inch water gauge on a 4 ft. by 4 ft. opening. This curve is indicative of results obtained with four ½-in. nozzles protecting an 8 ft. by 8 ft. opening. Higher pressure effects can be produced by using more nozzles or larger nozzles or by using the same nozzles working on a smaller opening.

Other factors investigated in addition to type and size of nozzles and angle of discharge were the effect of nozzle distance from the opening and the action of several nozzles used simultaneously.

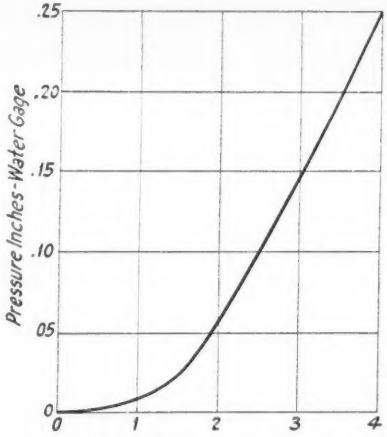


Fig. 2. Water spray—g.p.m. per sq. ft. of opening.

The Time Factor in Cooling.

One of the most important considerations in the protection of openings is the effective cooling capacity of the water spray. If, because of fire draft conditions or adverse wind effects, a definite movement of hot gases is set up through the opening, the theoretical cooling capacity required may be calculated if the air velocity and temperature are known. However, the cooling and rate of heat interchange between the hot gases and the drops of water depend not only upon the number and density of spray particles but also on the time in contact. This last named factor depends largely on the distance the hot gases must travel in order to pass completely through the spray zone.

Chimney Action in Buildings.

While we may lengthen the contact time by extending the spray zone by means of a short tunnel-like enclosure as shown in

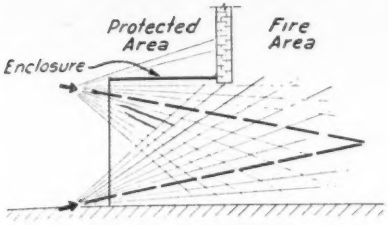


Fig. 3.

Fig. 3, the probable velocity of movement of hot gases through the opening cannot be definitely predicted. A rapidly spreading fire in flammable liquids or light combustibles will force air from a tight room through the conveyor opening. Even without such expansion effects, there will be a tendency to create a draft through the opening depending on the difference in average temperatures from one side of the wall to the other and on the height of the opening above floor level. The draft effect due to temperature for rooms of two representative ceiling heights is shown in Fig. 4. Furthermore, with openings through all floors in a high building, there will be normally quite a draft effect because of difference between inside and outside temperatures. For example, in a building 100 ft. high with inside temperature of 70° F.

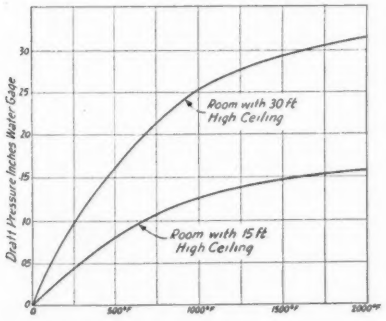


Fig. 4. Average room temperature above outside temperature.

and outside temperature of zero, the total stack effect would be 0.215 in. water gauge.

Effect of Wind.

Extremely unfavorable conditions can be caused by adverse winds. Data from *U. S. Bureau of Standards, Research Paper No. 301* (April, 1931) are shown graphically in Fig. 5. As an example, with a true wind speed of 20 miles per hour, the velocity pressure would be about 0.20 in. water gauge; and if this pressure should act on a building wall with open windows on the windward side and no openings on other sides, the resultant interior pressure would be about 0.14 in. water gauge according to wind tunnel tests on building models.

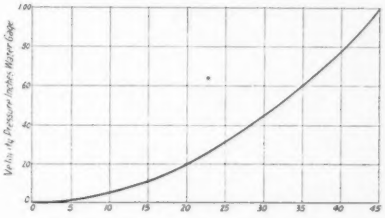


Fig. 5. True wind speed—m.p.h.

Considering the foregoing factors which might tend to produce movement of hot gases through conveyor openings, it seemed evident that our spray nozzle method would not always keep hot products of combustion confined to the original fire area. Consequently, it was assumed that such unfavorable hot air movement would occur under some conditions, even though at a rate much reduced because of the counterdraft effect of the spray nozzles.

Fire Tests at Norwood Station.

In order to try out experimentally the value of this general method in protecting openings in fire walls, an 8 by 8 by 16 ft. long plywood tunnel, representing an exposed area, was located at a double door

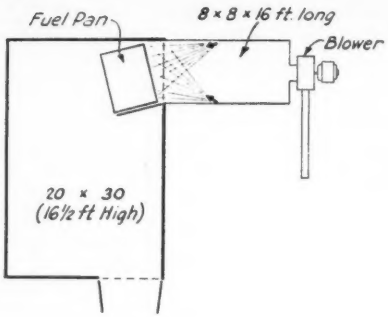


Fig. 6. Plan.

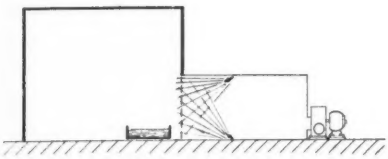


Fig. 7. Elevation.

opening in our smaller fire test building, which is approximately 20 ft. by 30 ft. by 16½ ft. high. The test arrangement is shown in Figs. 6 and 7. A blower was arranged to draw air from the building into the tunnel at a rate of 2400 cu. ft. per min. This would correspond to the volume expansion obtained by raising the temperature of the whole volume of a 20 by 20 ft. by 15 ft. high bay at the rate of 212° F. per min. It was thought that even with rapidly burning materials the air flow through a conveyor opening in a fire wall would not greatly exceed this amount unless the building itself was exceptionally tight or subject to adverse wind conditions.

The air in the building was heated by gasoline fires in shallow steel pans, the temperature at the tunnel inlet being varied by changing the location of the pan or its area. It was found ultimately, in order to make a reasonable test of the effectiveness of some nozzle arrangements, that a fire area as much as 48 sq. ft. of gasoline placed almost squarely in front of the opening was necessary. In most of the tests four ½-in. diameter orifice nozzles were used, but many tests were made with ⅜-in. diameter orifice nozzles. Other tests were made with smaller nozzles both on the full 8 by 8 ft. opening and on an opening 4 ft. wide by 6 ft. high.

Tests with ½-inch Nozzles.

Fig. 8 gives some typical results obtained by the use of four ½-in. orifice spray nozzles for the protection of the full 8 ft. by 8 ft. opening. These nozzles discharge each approximately 28 g.p.m. at 25 p.s.i. nozzle pressure with an effective angle of about 65°, and approximately 38 g.p.m. at 50 p.s.i. nozzle pressure with an angle of about 55°. The nozzles were located about 6 ft. back of the opening. The two upper nozzles were directed at the midpoints in the upper quarter sections; and the two lower nozzles were directed at points approximately 2 ft. below (that is, on the mid-height line).

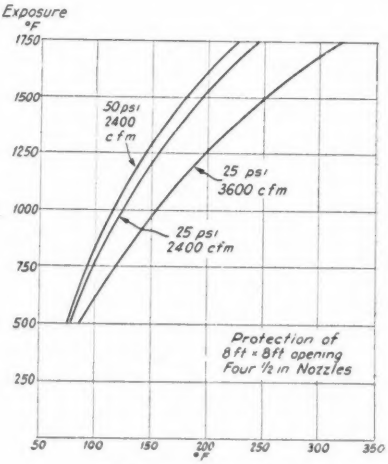


Fig. 8. Protected side.

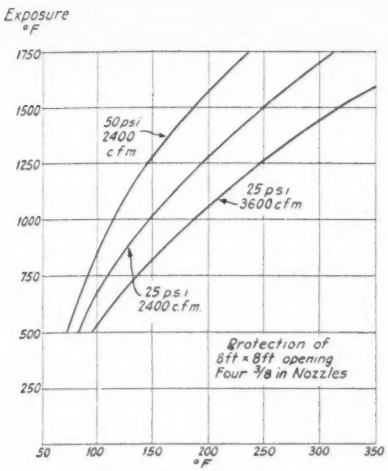


Fig. 9. Protected side.

It will be seen that, even with exposure temperatures around the order of 1700° F., temperatures were still kept well down below the point (about 450° F.), where ignition of relatively light combustible materials in the protected zone would be expected. Even when the air movement through the tunnel was increased from 2400 c.f.m. to 3600 c.f.m., tunnel temperatures still did not appreciably exceed 300° F. We did not consider it safe to attempt exposure temperatures beyond 1700° F., because under these conditions the piping under the test building roof was observed to be red hot and fires were started in the tar which dripped through the cracks in the 4-in. concrete slab roof itself. Ceiling temperatures underneath the concrete slab were in the vicinity of 2000° F.

Tests with 3/8-inch Nozzles.

Fig. 9 shows corresponding performance of four 3/8-in. orifice nozzles each discharging 16½ g.p.m. at 25 p.s.i. and 21 g.p.m. at 50 p.s.i. The discharge angles were approximately the same as the ½-in. orifice nozzles. This shows a more marked difference in the cooling capacity, depending upon the nozzle pressure. However, even at 25 p.s.i. and an air flow of 2400 c.f.m., tunnel temperatures were kept well below 400° F. with exposure temperatures around 1700° F.

Tests with Sprinkler Heads.

A few tests with ordinary ½-in. orifice sprinkler heads with the usual deflector have been made, and these tests showed a very good cooling action when hot gases were drawn through the spray discharge by the blower. However, the counterdraft effect of standard sprinkler heads was found to be negligible, so if used for protection of any opening the velocity of hot gas movement would be much greater than with a well-designed spray installation. Consequently, the practical cooling effect would be reduced proportionately.

Tests on Floor Openings.

Finally a few preliminary tests have been made on the protection of openings in floors or other horizontal cutoffs; but data are insufficient to form a basis for definite conclusions as to what can be accomplished in temperature reduction in the event of severe fire exposure. A few fires have been run in our new large test building (60 ft. by 120 ft.), both in the low section with 15 ft. head room and in the high section with 33 ft. head room. Fig. 10 shows the arrangement of nozzles

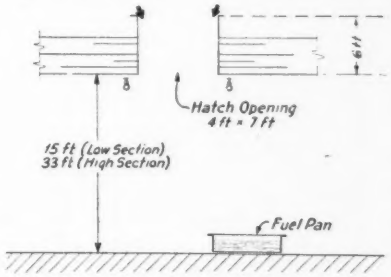


Fig. 10.

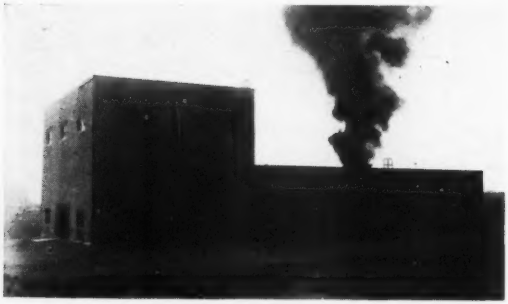


Fig. 11. 36 sq. ft. kerosene—no water.

Fig. 12. 36 sq. ft. kerosene—two ½ in. nozzles —25 p.s.i.

Fig. 13. 36 sq. ft. kerosene—two ½ in. nozzles —35 p.s.i.

Fig. 14. 36 sq. ft. kerosene—two ½ in. nozzles —50 p.s.i.

Fig. 15. 20 sq. ft. gasoline—no water.

protecting an opening in the ceiling of the low section.

Tests in the low section with a fire in 36 sq. ft. of kerosene below and slightly to one side of the 4 ft. by 7 ft. roof hatch are shown in the accompanying photographs. In each case the opening was protected by two ½-in. diameter orifice spray

Fig. 16. 20 sq. ft. gasoline—two ½-in. nozzles—50 p.s.i.

nozzles, one above each end of the hatch directed at the midpoint of each half section. Fig. 11 shows the smoke coming up through the hatch with no water on the nozzle. Fig. 12 shows that with water discharged at 25 p.s.i. the volume of smoke is decreasing. Fig. 13, with 35 p.s.i., shows that the smoke coming up through the hatch has almost disappeared. Fig. 14 shows that at 50 p.s.i. the draft is entirely reversed, with considerable black smoke billowing out from the open doorway at the other end of the building.

In tests run in the high section with the same protection but with a fire in 20 sq. ft. of gasoline on the floor below, Figs. 15 to 17 show that the draft reversal is not complete with 50 p.s.i. on the nozzle, but instead a pressure of 67 p.s.i. was required to reverse the air flow entirely. Fig. 18 shows the arrangement of nozzles at the top of the roof hatch.

Fig. 17. 20 sq. ft. gasoline—two ½-in. nozzles—67 p.s.i.

In two very recent tests in the high section an evaluation of the protection was attempted with a relatively severe exposure involving a fire in 48 sq. ft. of gasoline. The single open hatch (4 ft. by 7 ft.) was protected by two ½-in. nozzles arranged to operate automatically on the melting of a 160° F. fusible link. A large open-ended enclosure was built over the hatch-

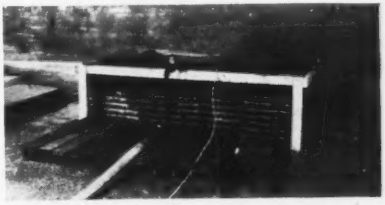


Fig. 18. Two ½-in. nozzles at top of roof hatch, discharging at 50 p.s.i.

way so that temperatures could be measured in the gases passing through the spray. With 25 p.s.i. on the nozzles the maximum temperature above the nozzles was 375° F.; and with 50 p.s.i. on the nozzles the maximum temperature was 285° F. In each case the fusible link operated in about 45 seconds after igniting the gasoline. With room temperatures between 750° and 800° F. and with a distance of 39 ft. from floor level to the top of the hatch combing, the stack effect was such as to cause a rapid flow of hot gases through the opening in spite of the opposing force of the water spray.

Fig. 19. 25 sq. ft.—two sprinklers below hatch—75 p.s.i.

Figs. 19 and 20 show the effect of locating nozzles or sprinklers below the roof hatch so that there is essentially no counterdraft effect. With a fire in 25 sq. ft. of kerosene, with either sprinklers or spray nozzles below the hatch, there is little change in the volume of smoke coming through, even at pressures as high as 70 to 75 p.s.i. On the other hand, with two spray nozzles located above the hatch to produce a counterdraft effect, only 25 p.s.i. nozzle pressure is required to reverse the fire draft, as shown in Fig. 21.

Discussion.

Our experimental work to date on this method of protecting openings has dealt primarily with fundamental operating characteristics, and details of practical installation have not been thoroughly worked out. In fact, at the present time commercial spray nozzles of the proper type and size are not generally available. However, we have some comments in regard to installations which may prove helpful.

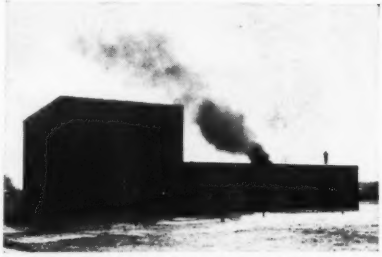


Fig. 20. 25 sq. ft. kerosene—two ½-in. nozzles below hatch—70 p.s.i.

The simplest installation would be one in which nozzles are arranged to prevent hot gases from traveling through the opening in only one direction. For the best results, it would seem that the water supply to the nozzles should be controlled by an automatic valve actuated by some suitable heat detector located on the side of the cutoff in which the exposing fire is to be expected. In most cases the heat detector need be no faster than an ordinary fusible link or the standard approved sprinkler head. It is quite likely that automatic spray nozzles of the proper characteristics could be used, especially with small openings

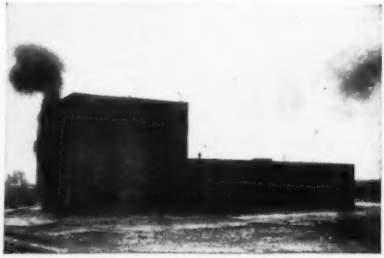


Fig. 21. 25 sq. ft. kerosene—two ½-in. nozzles above hatch—25 p.s.i.

and for those in which the conveyor can be enclosed from the fire wall back to the location of the spray nozzles.

If two-way protection is needed, then spray nozzle protection would have to be installed on both sides of the wall, each nozzle system being actuated by proper controls located on the opposite side. Nozzles could be placed on both sides of the wall opening and arranged to discharge opposing each other, both sets of nozzles to be operated simultaneously through a single control valve. Such an installation would provide a superior cooling action but would have no effect one way or the other in preventing movement of air or hot gases through an opening.

When using a system of spray nozzles to counter a fire draft in a single direction only, it is well to keep in mind that such a system will force air from the protected zone into the fire area; and may also force air from the fire area through any other openings, whether to outdoors or even into other rooms. Therefore, any communicating doorways to other areas should be closed or protected with automatic fire-doors in the usual manner. Openings from the fire area to outdoors would be beneficial unless subject to adverse wind pressure.

In considering the protection of conveyor openings through floors, we are interested only in preventing the passage of fire due to upward travel of hot gases. The protection system would be a one-way proposition, locating spray nozzles above the opening, arranged to deliver downward at the plane of the opening. There is no reason why automatic spray nozzles could not be used for such openings if an enclosure is constructed around the conveyor from the floor up to or slightly beyond the spray nozzles themselves.

One of the unanswered questions in regard to this method is "How good is it compared to a fire wall with no opening at all?" This question cannot be answered at present, although we have no idea that it is as good as an unbroken fire wall. However, it appears to be an improvement over former methods of protecting conveyor openings where fire doors or shutters are impracticable. We do know that our brick and concrete test building has taken a terrific beating from many severe fires, while our ⅜-in. thick plywood tunnel is still intact. A more exact evaluation of its relative worth will have to wait until further tests and experience have supplied the answer.

Recommendations.

Based on our experimental work to date, we have a few suggestions which should be kept in mind in order to obtain the best results: Objects passing through an opening on a conveyor will present some interference to water distribution; consequently, it will usually be desirable to use four nozzles in order to get complete coverage of the opening.

Water discharge rates of less than 2 gals. per sq. ft. per min. are not recommended. For high ceilings or openings at high elevations above floor level (especially over 15 ft.) and for locations where unfavorable draft effects may be expected, higher rates discharge up to 4 gals. per sq. ft. per min. or even more would be indicated. Nozzle spray discharge angles should be chosen with respect to distance from the opening so that the latter is well covered with dense spray with a minimum of wastage outside of the opening area. There will be less loss of spray cooling capacity if an enclosure is used.

Spray nozzles should be located preferably to discharge at an angle not more than 30° between the center line of nozzle

discharge and a line perpendicular to the plane of the opening. Nozzles of ½-in. diameter orifice may be located from 5½ to 6 ft. away from the opening and still produce a good counterdraft effect. Locations from 8 to 10 ft. away will give superior cooling with no loss in counterdraft effect if the conveyor is enclosed 4 or 5 ft. back from the opening.

Nozzles of ⅜-in. diameter orifice should be located from 4 to 4½ ft. away from the opening unless an enclosure is used, when the distance may be extended to 6½ to 8 ft.

Since both the counterdraft effect and the cooling capacity are much improved by increased nozzle pressure, it is essential that the water supply piping to the nozzles be generous in size so as to result in the least friction loss.

Finishing Floors and Bowling Alleys

By C. L. Jones,*
(Member N.F.P.A.).

It is not always appreciated that there are personnel hazards connected with the finishing of floors, bowling alleys and other large surfaces. These hazards exist during the sanding operation and later when the floor finishing material is put on and until practically all of the solvent has evaporated.

To finish a floor, a sanding machine (usually power-driven) of some type is used. The sanded-off material is usually caught in some sort of container, frequently in a cloth bag.

The Sparking Hazard.

The floor or other surface being sanded may have imbedded in it particles of sand, cinders or other hard material. Furthermore, nailheads may be exposed; and when the sanding paper strikes such surfaces, sparks are frequently struck and as the fan picks up the finely cut material and discharges it into the bag or other container, any spark which is struck can be carried into the bag, where the dust-air mixture may be in the flammable range. If this condition exists at the time a spark is struck, a flash fire may result.

In addition to the above spark hazards, frictional heat due to the use of dull or improper paper also can cause the firing of the dust-air mixture in the bag.

The total amount of combustible material which is present in the bag may be small; but a small volume of such dust-air mixture is sufficient to create a reasonably large volume of flame, because it burns the bag and flares into the atmosphere.

While the sander operator is guiding the machine, he is in a position to be exposed to the blast of flame and can be burned severely. This has happened in several cases, and in some instances the burns have resulted in death.

The U. S. Department of Agriculture, Bureau of Chemistry and Soils, has accumulated a large fund of data concerning the flammability of various dusts, including wood dusts, and the figures which are quoted below illustrate the point that wood and other dusts are quite flammable if they are finely divided and if oxygen is present.†

Maximum explosion pressures developed by finely divided materials in concentration of 0.1 oz. per cu. ft. of air.

White pine	44 psi
Long leaf yellow pine	43 psi
Maple	37 psi
Oak	40 psi
Cedar	40 psi
Spruce	39 psi
Coal (Bituminous)	42 psi

It should be understood that the pressure developed and the rate at which the pressure builds up depend on several factors, such as concentration, fineness, the degree of confinement, source of ignition and possibly other factors. Concentrations other than those quoted will, upon ignition, produce pressures different from those given. However, the comparison between coal and wood dust illustrates quite clearly that wood dusts and bituminous

*Safety Engineer, Hercules Powder Co., Wilmington, Del.

†See U.S.D.A. Technical Bulletin 490, October, 1935.

coal dust are not greatly different in their degree of flammability. It is well known that a number of serious coal dust explosions have occurred in mines and in other places where finely divided coal exists.

Any coating materials which may be removed during the sanding operation are likewise flammable and will burn rapidly when in the finely divided state and suspended in and mixed with sufficient air; for example, shellac dust, in a concentration of 0.1 oz. per cu. ft. of air, will develop a maximum explosion pressure of 31 psi.

No figures are immediately available for the flammability of varnish dust. However, data available for rosin show a maximum explosion pressure of 32 psi for a concentration of 0.1 oz. per cu. ft.

Nitrocellulose lacquers are widely used today for the finishing of floors, bowling alleys and other surfaces. This material is a mixture of nitrocellulose, resins and plasticizer, and these ingredients are flammable. Figures are given below as to the pressure developed on the burning of nitrocellulose lacquer dust and air. The pressures developed upon the burning of these dusts are similar in magnitude to those developed upon the burning of the wood and other dusts cited previously.

Maximum pressures developed by ignition of dust from bowling alley surfaces, in concentration of 0.1 oz. per cu. ft. of air.

Top cut material from bowling alley surface ..... 44 psi

Finishing cut material from bowling alley surface..... 44 psi

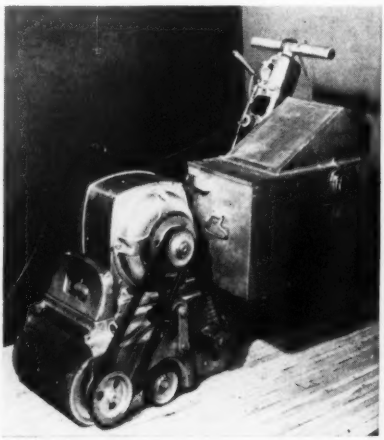
The top cut material contained some lacquer ingredients and, of course, some wood dust. The finishing cut material was probably largely wood dust, although it may also have contained some lacquer ingredients.

While these data indicate that the first and second cut materials will produce about as much pressure when burned (in confinement), there is another difference of some importance — namely, the ignition temperatures. It was found that the first cut material was ignited at a temperature of about 350° F., the second cut material at about 500° F. Therefore, it is important to reduce the possibility of ignition of either material, and several precautions are indicated as follows:

On bowling alleys which have been heavily oiled, the surface should be thoroughly cleaned of oil before attempting to make the first cut.

Other matters of importance are the use of the proper kind of paper for the first cut and the need of discarding paper before it loses its cutting efficiency. Dull paper or improper paper will quickly generate heat, and a temperature may be reached which could cause fire.

As it is not practical to eliminate all sparking or ignition sources, it is important to prevent the formation of a dust-air mixture in the flammable range in any



Brunswick-Balke-Collender Co.
Floor sander with water tank.

Emptying water tank.

considerable volume, such as may exist in a conventional bag on a sander. This can be and has been accomplished by replacing the sander bag with a small tank containing a few gallons of water. As the material is cut from the bowling alley or floor it is discharged by means of a fan into the water, where it is immediately wetted and made harmless. The sander water tank has been made as large as practical, but on some jobs it may be necessary to empty the tank after one trip down an alley.

At suitable intervals the accumulated residue from various dumpings of the tank can be taken to a safe location, the water poured off, and the excess water wrung out of the material by hand. The wrung material should be spread out on paper or other combustible material and burned.

The accompanying illustration shows a sander equipped with a water tank for catching the sanded off material. A number of sanders so equipped are in regular use. No fires have occurred since these machines were put into use, and a number of them are being regularly used. Furthermore, sparks have been observed being extinguished by the "wet" sander. The use of the "wet" sander appears to eliminate the danger of burns to the operator.

The Solvent Hazard.

Various quick-drying finishes, including lacquers, most of which contain volatile solvents and diluents, are widely used as finishing materials for floors, bowling alleys, etc. Most of the solvents and diluents used evaporate readily and have sufficiently low flashpoints so that at ordinary room temperature a flammable vapor-air mixture will exist near the freshly coated surface until most of the solvent has evaporated.

The quantity of 100 per cent vapor which is produced at normal temperatures and pressure (68° F., 29.92 in. mercury) by any given solvent may be calculated by the following formula:

$$\frac{A \times B}{C} \times 359 = \text{Cu. ft. of vapor, where}$$

A = number of gallons of solvent
B = pounds weight per gallon
C = molecular weight of solvent

The quantity of 100 per cent solvent vapor produced by the evaporation of a gallon of a few commonly used solvents and diluents, and the amount of flammable vapor-air mixture which can be formed have been calculated, using the above formula. These data are shown in the table on the next page.

One gallon of a fast drying finishing material may contain as much as three-fourths of a gallon of volatile solvent and diluent; and this quantity of solvent and diluent can produce upon evaporation a relatively large amount of flammable vapor-air mixture. In many cases a relatively large surface will be coated with lacquer, and this wetted surface can,

Flammable Vapors from Evaporation of Solvents.

Solvent or Diluent	Quantity (Gallons)	Quantity of 100% Vapor Produced (cu. ft.)	Lower Limit of Flammability % by Volume	Maximum Quantity of Flammable Mixture Produced by one gallon of solvent (Cu. ft.)
Butyl Acetate.....	1	22.22	1.7	1307
Butyl Alcohol.....	1	32.35	1.68	1925
Ethyl Acetate.....	1	29.99	2.3	1298
Ethyl Alcohol.....	1	52.91	3.5	1511
Toluene	1	28.09	1.27	2211

within a relatively short period of time, give up by evaporation enough solvent vapor to form several thousand cubic feet of flammable vapor-air mixture. But if the facts cited are recognized and proper precautions are taken, lacquers and volatile solvents can be used with reasonable safety.

Precautions Are Simple.

The necessary precautions are few, simple, easily provided and carried out. The persons applying the finishes should not smoke or permit a spark or flame of any kind near where the work is being carried out, or during the evaporation period. The application of coating material should not be carried out if there are any fixed sparking or flame sources nearby, such as motors, switches, pilot lights, heaters, etc.

A particular point to keep in mind in this connection is the relative density of solvent and diluent vapors as compared to the density of air. Ethyl alcohol vapor is about 50 per cent heavier than air, ethyl acetate vapor is nearly three times heavier than air, and toluene vapor is about three times heavier than air. This means that such vapors will drift or flow and tend to accumulate in low spots.

The accumulation of such vapors which are invisible in low spots or poorly ventilated spaces is the real source of danger.

If there is a heater or other source of ignition present, the vapor-air mixture reaching the heater can be ignited, and the flame can flash back and involve the whole coated surface; that is, if it is still wet and the solvents are evaporating.

Thorough and comprehensive tests of several coating materials, including lacquer applied to flat surfaces of both wood and steel, indicate that such films in the thicknesses ordinarily used, about 4 mils (.004 inch), will not propagate flame after becoming dry even when a direct flame of considerable size is applied to them. The films will burn in the immediate vicinity of the applied flame, but they will not burn to any appreciable distance beyond the applied flame. Very thick lacquer films when subjected to flames will no doubt result in propagation. The thickness required for flame propagation is unknown; however, it is thought that film thickness somewhat greater than 10 mils (.010 inch) may be hazardous. Therefore, it will be advisable to prevent build-up much in excess of such a thickness.

Another simple and important fact to keep in mind when applying any of the quick drying finishes is that adequate ventilation should be provided to avoid confinement of such vapors. For example,

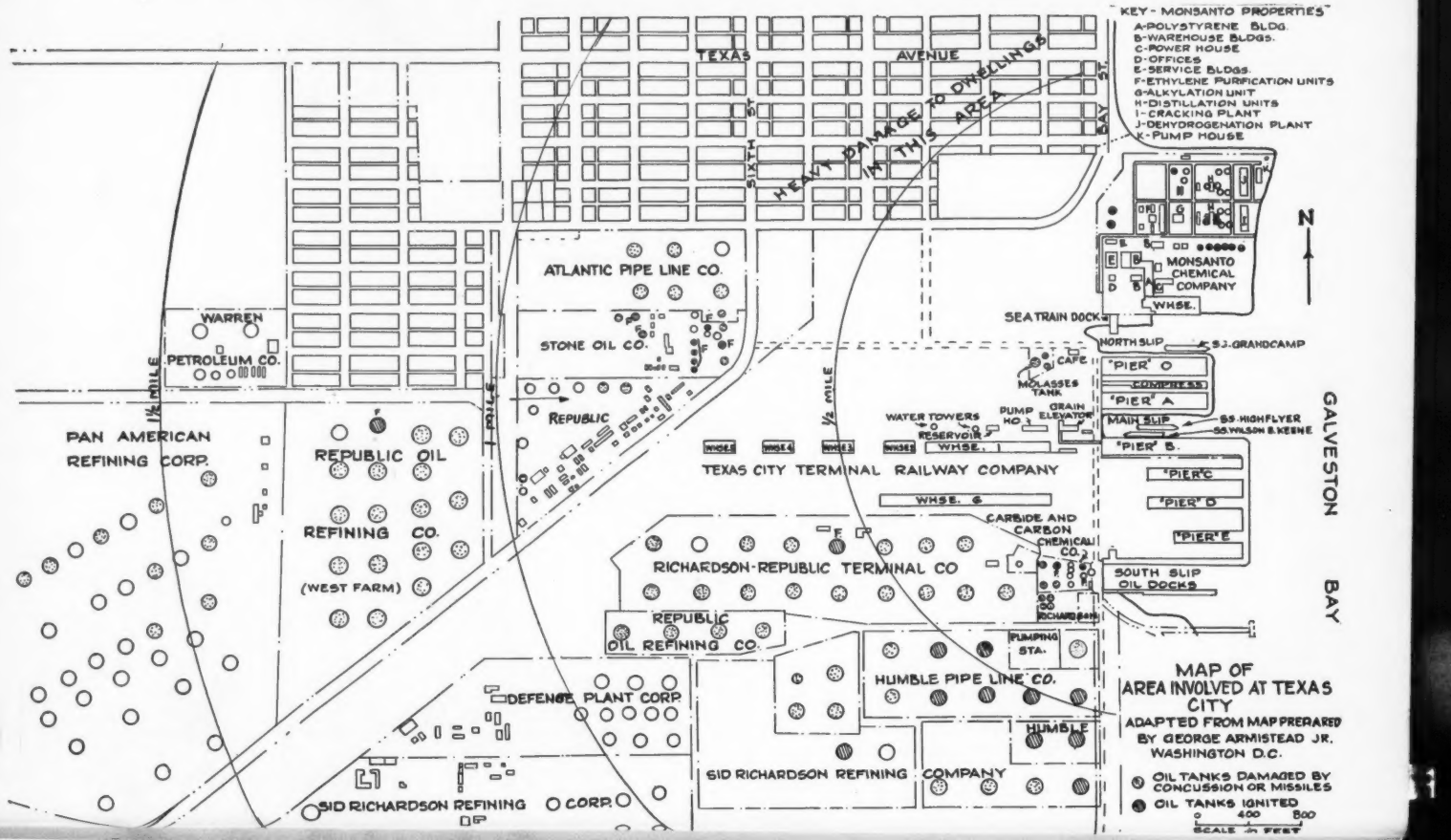
if a bowling alley or a large floor is being coated, the windows and doors in the building should be open so there will be good diffusion of the vapors, and to prevent the formation of a vapor-air mixture in the flammable range. It is good practice, of course, to ventilate whether the surface being coated is large or small. If the ventilation provided by the opening of the windows and doors is not sufficient to prevent such vapor-air accumulation, then temporary forced ventilation, such as by means of a portable ventilating fan, should be provided. The fan used should be driven by an explosion-proof motor, Class I, Group D, and the fan blades should be made of some nonsparking metal. The switch controlling the fan motor should also be Class I, Group D.

At times, consideration may be given to the use of a fan driven by a conventional "open" type motor for blowing air into the building. With such an arrangement, there should be no vapors near the fan motor itself. The use of this type motor is not advisable, however, because the fan might be placed at a location where there could be a vapor-air mixture in the flammable range; then if sparking at the motor or its switch should occur, the vapor-air mixture would be ignited. In some cases, the fan might be placed to draw the vapors from the building. In such a case, the vapors, of course, would pass through the fan and around the motor; then if vapors were in the flammable range and if there should be sparking, ignition would occur. For these reasons, any portable fan, irrespective of use, should be explosion-proof.

It will be advisable to have an approved fire extinguisher convenient, while carrying out the sanding and also when applying the coating. A 10-pound CO_2 or dry powder extinguisher is suggested as being a reasonable size.

A potential hazard exists with a great many of the materials, devices, and equipment which have a wide distribution and use. If those hazards are recognized and reasonable precautions taken, the advantages that such things provide can be enjoyed without penalty. On the other hand, if reasonable precautions are not observed the consequences can be serious.

The above line of reasoning applies to the simple job of refinishing floor surfaces. Knowing that many finely divided materials will burn, and burn violently when mixed with air, no one should expose himself to the possibility of a fire or flash which may result from the burning of the finely divided materials resulting from floor sanding operations. Also, the same line of reasoning applies to the handling and use of fast drying finishes or other materials which are volatile and flammable. It is believed that the precautions outlined above, if followed as they should be, will do much to prevent fires which may involve both property and persons, and if involving persons, may result in the loss of life.


KEY - MONSANTO PROPERTIES
A-POLYSTYRENE BLDG.
B-WAREHOUSE BLDGS.
C-POWER HOUSE
D-OFFICES
E-SERVICE BLDGS.
F-ETHYLENE PURIFICATION UNITS
G-ALKYLATION UNIT
H-DISTILLATION UNITS
I-CRACKING PLANT
J-DEHYDROGENATION PLANT
K-PUMP HOUSE
TEXAS AVENUE
SIXTH ST
BAY ST
HEAVY DAMAGE TO DWELLINGS IN THIS AREA
ATLANTIC PIPE LINE CO.
STONE OIL CO.
WARREN PETROLEUM CO.
1½ MILE
1 MILE
½ MILE
REPUBLIC
PAN AMERICAN REFINING CORP.
REPUBLIC OIL REFINING CO. (WEST FARM)
MONSANTO CHEMICAL COMPANY
WHSE.
SEA TRAIN DOCK
NORTH SLIP
S.J. GRANDCAMP
CAFE
MOLASSES TANK
'PIER' O
COMPRESS
'PIER' A
WATER TOWERS RESERVOIR
PUMP HO.
GRAIN ELEVATOR
MAIN SLIP
SS. HIGHFLYER
SS. WILSON B. KEENE
'PIER' B.
'PIER' C
'PIER' D
'PIER' E
TEXAS CITY TERMINAL RAILWAY COMPANY
WHSE. 6
CARBIDE AND CARBON CHEMICALS CO.
RICHARDSON-REPUBLIC TERMINAL CO
SOUTH SLIP OIL DOCKS
REPUBLIC OIL REFINING CO.
PUMPING STA.
HUMBLE PIPE LINE CO.
HUMBLE
DEFENSE PLANT CORP.
SID RICHARDSON REFINING COMPANY
SID RICHARDSON REFINING CORP.
GALVESTON BAY
N
MAP OF AREA INVOLVED AT TEXAS CITY
ADAPTED FROM MAP PREPARED BY GEORGE ARMISTEAD JR. WASHINGTON D.C.
OIL TANKS DAMAGED BY CONCUSSION OR MISSILES
OIL TANKS IGNITED
0 400 800
SCALE IN FEET

The Texas City Disaster.

A Staff Report.*

Four hundred and sixty-eight persons are known to have lost their lives, over a hundred are still missing (July 1, 1947), and 3000 were injured as the result of fires and ammonium nitrate explosions aboard two ships docked at Texas City, Texas, April 16-17, 1947. Property damage and contingent losses are estimated at $67,000,000.

The account of the disaster in this staff report is presented as follows:

I. Introduction.
II. Chronological Sequence.
III. Conclusions.
IV. Losses.
V. Details.
  A. Texas City Terminal Railway Co.
  B. Monsanto Chemical Co.
  C. Oil Tank Farms and Refineries.
  D. City of Texas City.
  E. Miscellaneous Properties.
  F. The Ammonium Nitrate Fertilizer.
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I. Introduction.

The terrible disaster resulted from the explosive decomposition of ammonium nitrate fertilizer under fire conditions.

The tremendous violence of the blasts resulted from the formation of large volumes of decomposition gases within the confined areas of the holds of the ships involved.

The large loss of life occurred because of the immediate proximity of persons engaged in the industrial activity of the port and its exposed properties. This concentration of population was augmented by firemen and a considerable number of curious persons who had been attracted to the scene by the pre-explosion fire.

The huge property destruction occurred because of the direct exposure to blast damage of high valued industrial plants and facilities. Much of this property was particularly vulnerable to blast damage and self-propagated resultant fires because of the flammable nature of materials employed in the processing activities or stored preparatory to shipment or use.

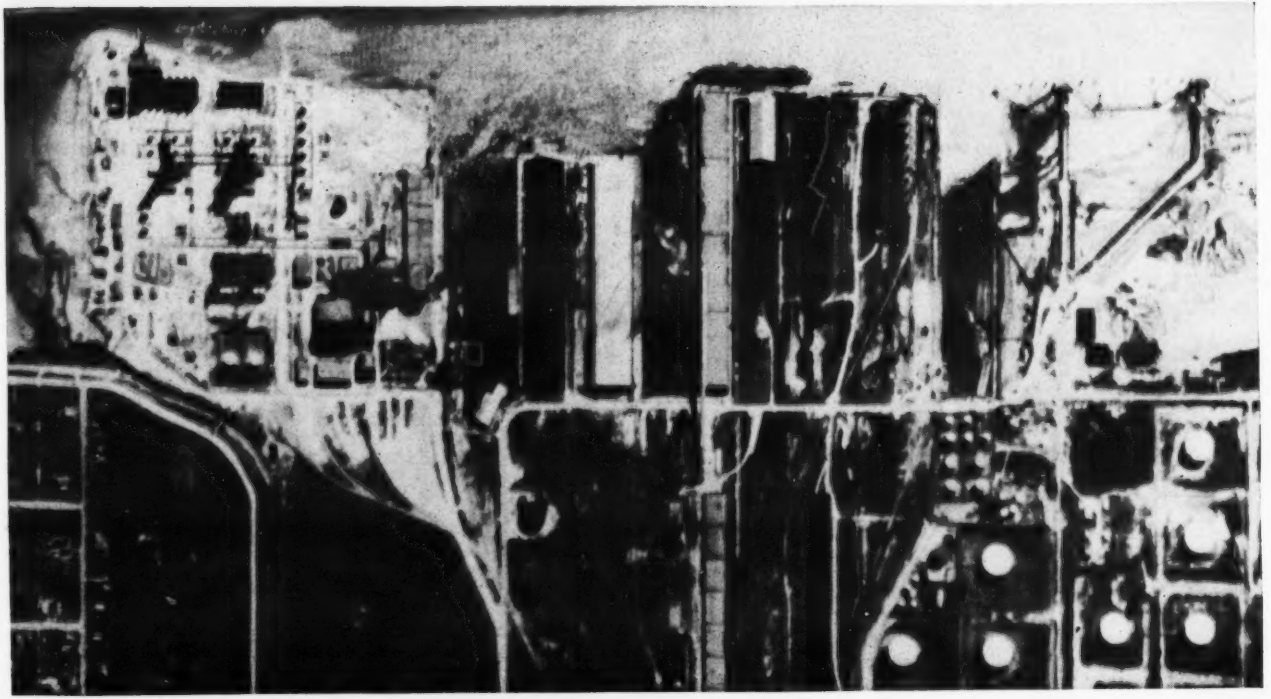
*See Section VI for sources of information.

II. Chronological Sequence.

Prior to 8:00 A.M. April 16, the 7000-ton Liberty vessel S.S. *Grandcamp* had been loaded with approximately 2300 tons of ammonium nitrate fertilizer. It was berthed in the North Slip, adjacent to "Pier O," of the Texas City Terminal Railroad Company's docking facilities. The vessel was owned by the Republic of France and operated by Compagnie Generale Atlantique, commonly known as the French Line. It had arrived at Texas City on the morning of April 11. Loading operations had commenced that afternoon. The ammonium nitrate fertilizer had been shipped to Texas City via rail on government bills of lading from three Midwest ordnance plants. The fertilizer was shipped, handled and was being stowed in the *Grandcamp* in 100-pound, 6-ply, moistureproof paper bags marked: "Fertilizer, Ammonium Nitrate, Nitrogen 32.5%." The material had been stored in the warehouse on "Pier O" and stevedores were loading the vessel from this source.

Approximately 1400 tons had been stowed in No. 2 hold and 880 tons in lower No. 4 hold when loading operations ceased at 5:00 P.M. April 15. Other cargo in separate holds included cotton, binder twine, peanuts, boxed machinery, oil well equipment and 16 boxes of small arms ammunition.

Loading operations were resumed about 8:00 A.M. on the 16th in lower hold No.



U. S. Army Air Forces.

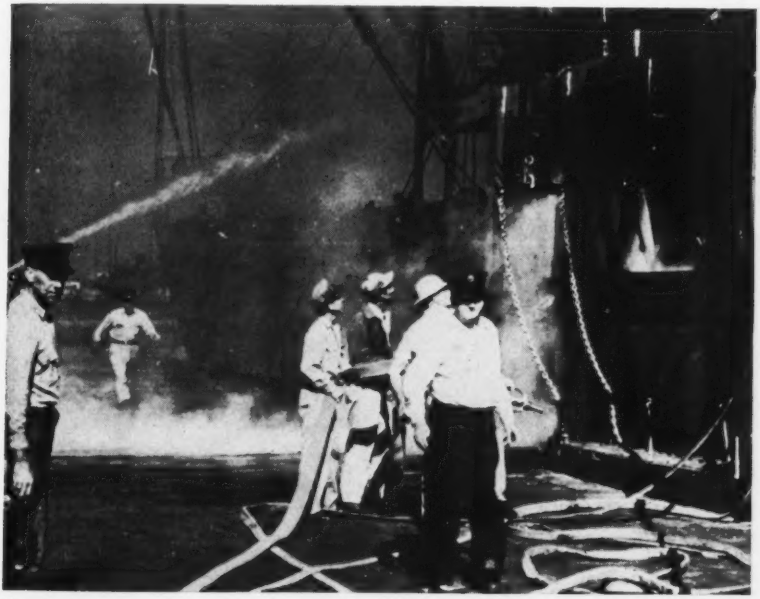
Vertical photograph of Terminal before the explosion. Monsanto plant at left, with South Slip (where *Grandcamp* was berthed) adjacent. The *High Flyer* was in the Main (center) slip adjacent to the longest fire-resistive warehouse. Note relation to oil tank farms at lower right.

4. No fire or smoke was visible at this time according to survivors. One crew of four workmen commenced to stow bags of the fertilizer already in the hold on the port side of the vessel. A second crew of four sat down on the starboard side to await further supplies from topside. It is believed one or more of this idle crew smoked a cigarette during the interval. There was known to be smoking on the main deck.

The First Fire.

About 8:15, smoke was observed in lower No. 4 hold on the starboard side issuing from an open space about 8 inches wide between the hull and cargo battens. Attempts were made to extinguish the fire with drinking water and hand fire extinguishers, but flames were observed to increase along the starboard side. The ship's whistle was sounded to give the alarm and all persons were ordered out of the hold. A ship's fire hose was lowered into the hatch, but the first mate (known as second captain on French ships) ordered that no water be used as it would damage the cargo. (Water was available and the ship's fire pump operating at full working pressure.) The hatch was then covered, a tarpaulin put in place and wet down, vent cowls were sealed, and steam introduced into No. 4 hold through the installed steam smothering system.

It was 8:30 by this time and the smoke continued to increase despite efforts to smother the fire. A telephone alarm of fire was received about 8:30 by the Texas City Fire Department. Two fire trucks responded immediately, followed by the two remaining pieces of apparatus. A total of 27 volunteer firemen responded out of the total 50 members of the department. Crew members of the *Grandcamp* left their ship and assembled on the adjoining



Press Association.

Texas City firemen fighting the fire aboard the *Grandcamp* prior to the explosion. Note one hose line in service, others being prepared. All 27 firemen who responded were killed by the blast.

U. S. Army Air Forces.

Vertical photograph of Terminal before the explosion. Monsanto plant at left, with South Slip (where *Grandcamp* was berthed) adjacent. The *High Flyer* was in the Main (center) slip adjacent to the longest fire-resistive warehouse. Note relation to oil tank farms at lower right.

pier to assist firemen who stretched hose lines from dock-side hydrants. Photographs taken between 8:30 and 8:50 show one hose stream in use from the dock with another line being assembled, but it has not been possible to determine precisely what fire fighting was accomplished before the explosion.

Pressures were being built up within the ship's hold as the hatch covers blew off and an orange-brown smoke (characteristic of oxides of nitrogen) was observed. The hull in the way of the fire was sufficiently heated to vaporize water running off the deck before it reached the surface of the slip.

The First Explosion.

The explosion occurred at 9:12 A.M.

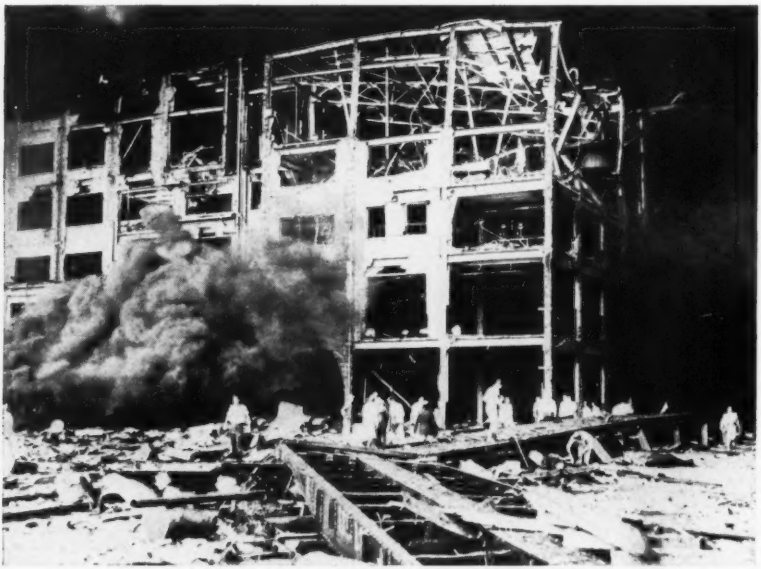
Those on the pier fighting the fire and over 400 others in the vicinity were killed, the great majority instantaneously. Others, felled by the blast, were cremated by ensuing fires.

The *Grandcamp* completely disintegrated and fragments were thrown in all directions.

Missiles, varying in size from large sections of ship's plate weighing tons to compact fragments weighing less than a pound, were thrown through the air for thousands of feet, leveled some structures, damaged others, pierced oil tank roofs, crushed automobiles, severed railroad tracks and buried themselves in the ground. Heated missiles ignited flammable vapors at their source while others split tanks and released vapors which were subsequently ignited from friction sparks or open flames in the vicinity.

Explanation of Shock Waves.

Concussion damages were most severe. They took three distinct forms. First, the initial shock waves leveled such buildings as Warehouse O, the Monsanto warehouse building directly across the slip,



Acme.

Damage to the five-story polystyrene building of the Monsanto Company while fires were still burning in the area. This building received direct explosion blast from the *Grandcamp* across a distance of only 350 ft.

Los Angeles Fire Dept.—Capt. Conlin.

View of Monsanto property, showing wall failures in warehouse at right and damage to office building at left.

and caused severe direct concussion damages to other structures within range. Two private airplanes were knocked out of the sky, and their occupants killed.

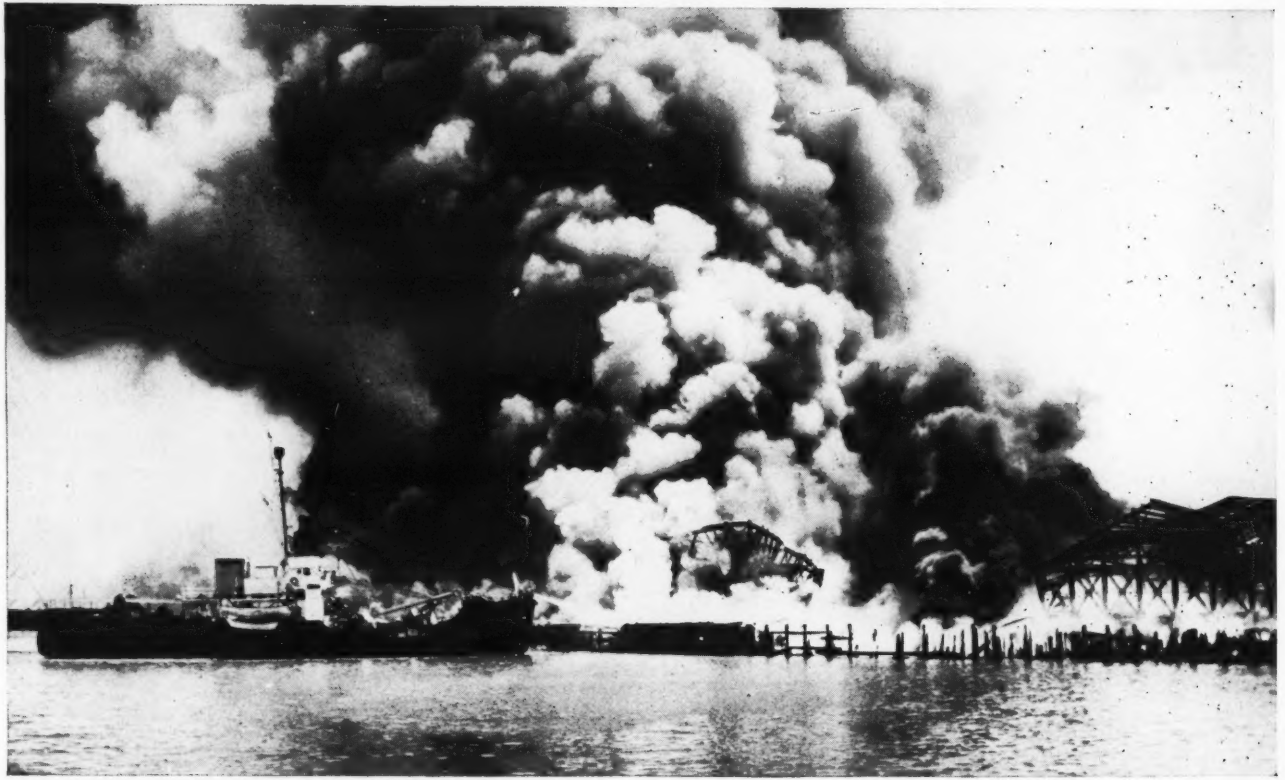
It seems substantiated that the only major explosion was the nitrate cargo at this hour, although there were minor tank explosions immediately thereafter. Residents of the area who speak of other major blasts shortly after the initial explosion are believed to have confused the time differential between the shock and sound waves or to have been mystified by the pattern of the shock waves themselves.

Some of the blast effect was deflected by the impact with substantial nearby structures, and since the explosion occurred in lower No. 4 hold of the *Grandcamp,* the horizontal forces, as initially applied against the water in the slip, were deflected at a high angle. These deflected shock waves formed a second high pressure effect. A very definite pattern, in terms of distance from the scene of the explosion, is evidenced by damages caused by the deflected waves. Buildings affected by such concussion waves show the effect of downward forces of high magnitude as contrasted to buildings where concussion was obviously horizontal. Many of these buildings were clearly shielded from the direct concussion forces.

Despite this deflection, sufficient force was applied on the water in the North Slip (depth 30 ft.) to drive it shoreward. The volume of water displaced was adequate to lift a steel barge (11 ft. draft, 150 ft. long, 28 ft. wide) and deposit it 100 ft. inshore.

Beyond this, there was evidence to support the thesis that a third type of blast damage occurred. This was occasioned by the negative pressure front or vacuum created by the displaced air at the core. Properties affected were those on the outer rim of the explosion-rocked area. The vacuum effect was manifested by upward thrusts on roofs of buildings, automobile engine hoods, and outward fragmentation of glass windows.

Another result of the first blast was that the S. S. *High Flyer* (a C-2 cargo vessel of American registry) was blown across the main slip where it was berthed at Pier A to lie against the Liberty ship, S. S. *Wilson B. Keene.* This was significant when the *High Flyer* caught fire later on in the day.



Press Association.

Fires in Warehouses C, D, and E from the Bay side. Docking in front of Warehouses was wood plank on wood piles and supported oil pipe lines used for bulk shipments from this Terminal.

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Fires Following the First Blast.

The fires occasioned by this initial blast are best portrayed photographically. The Monsanto plant was literally engulfed in flames. In the main, these fires were caused by the ignition of combustible hydrocarbons, especially in the polystyrene building, the ethylene purification units, the process equipment and control facilities of the alkylation unit, the distillation towers and the fourteen main storage tanks of benzol, fuel oil, and other low vapor pressure hydrocarbons. Ground fires spread fire damage to piping and were fed by flammable liquids which escaped from broken or melted lines. The fact that the highest pressure on equipment in the plant was around 15 pounds was a factor which must be credited, at least partially, with the fact that there were no separate explosions in the Monsanto plant area.

The Terminal Warehouses O and A, and the frame compress between these buildings, were immediately involved. Sulphur stored in Warehouse A was ignited, giving off noxious fumes. What other Terminal buildings were immediately involved in fire cannot be definitely established because of the extent of concussion damage, the subsequent explosion of the *High Flyer,* which destroyed evidence, and the heavy smoke which drifted with the 20 mph wind over the entire area. There were fires, however, on the water edge of piers as far as the south slip, presumably from oil pipelines that had parted by concussion or had been pierced by missiles. It is also positively established that six tanks in the Stone Oil Co. farm and one in the Richardson-Republic farm ignited. All other oil tank farm fires were caused by the *High Flyer* explosion.

During the period between 9:12 and 1:10 A.M. the following morning, the scene was one of unparalleled tragedy, mitigated only by many exhibitions of personal sacrifice, individual heroism, and distraught initiative.

Rescue Activities.

Rescue efforts were the first order of business. Fire fighting in the Monsanto and Terminal area was impossible. Even the Coast Guard cutter *Iris* could not approach the docks for effective fire suppression following its 10:40 A.M. arrival from Galveston. It picked up survivors in the water and returned to its station. The 27 Texas City firemen on duty at the *Grandcamp* were killed outright. Their total of four pieces of fire apparatus was wrecked. Other volunteer members of the department responded to the emergency following the explosion, but the water supply systems in both the Terminal and Monsanto areas were inoperative due to explosion damage. Drafting water from the slips or bay was barred by fires and wreckage. Houston fire equipment and manpower drove 50 miles to the scene following commercial radio broadcasts of the disaster. Army fire-fighting crews from Fort Crocker were dispatched by the Commanding Officer, who observed the smoke and felt the explosion. There was no direct call for assistance to these or other neighboring fire departments on the 16th, although other communities also responded with pumpers and manpower on their own initiative. All fire-fighting personnel, including local plant brigades, concentrated on rescue work except at the Stone and Richardson-Republic tank farms which were segregated from the main explosion-damaged area. Fire equipment, in the main, was parked in the school yard in the town during the first day.

The uninjured crews on the *High Flyer* and *Wilson B. Keene* found their position untenable due to the smoke and sulphur fumes, and abandoned their ships at 10:30 A.M. The *High Flyer* could not be moved under its own power as its main turbine casing had been removed for inspection. An anchor was lowered to hold the vessel in place. The *Keene* was also "dead" because of blast damages. Two

tugs which were despatched from Galveston at 8:50 arrived at the Texas City turning basin at 9:50 A.M., but could not enter the harbor due to dense smoke, fumes, and debris. The tugs picked up survivors and returned to Galveston. The *Iris* returned to Texas City at 3:00 P.M., but again could not enter any of the three slips for fire fighting and left at 7:40 P.M.

Fourth Army, Red Cross, and Salvation Army rescue and medical workers rushed to the area. The small Galveston Red Cross Chapter was sending help to the scene within thirty minutes. The readily available services of the Fourth Army from headquarters at Fort Sam Houston, Fort Crockett, Ellington Field, San Jacinto Ordnance Depot, and the Galveston District Engineer were invaluable until the Red Cross could muster sufficient personnel to handle the emergency. (The tornado in Texas and Oklahoma on April 9th had drained normally available Red Cross workers in the Southwest.) An indication of the efficiency of rescue work may be gleaned from the statistics of the University of Texas Medical Branch. Within the first five hours this one hospital in Galveston handled 360 casualties. A deactivated hospital at Fort Crockett was placed in service by 6:00 P.M. and was handling patients (total admissions, 121 persons). The Fourth Army sent 9000 lbs. of blood plasma from Austin, medical personnel (69 officers, 50 nurses and 232 enlisted men), plus surgical equipment, food, gas masks, heavy road and construction equipment, and similar emergency relief supplies. Army aircraft brought needed medicines from St. Louis supply centers. Army specialists in gas gangrene were flown to the scene. General Wainwright, commanding the Fourth Army, had joined Governor Jester of Texas at the scene by 4:20 P.M. to speed all possible relief to the area. There was no lack of succor for the victims of the disaster on the part of relief organizations and the Army despite the lack of an integrated community disaster plan. However, the existence of a Disaster Plan would have speeded the organization of the several agencies involved.

Further Trouble Brewing.

While rescue work was proceeding, further trouble was brewing for the already heavily damaged port. The *Grandcamp* blast carried away the hatches of the *High Flyer,* jumbled the cargo, sprang the steam lines, distorted and deflected the superstructure and decks, besides injuring the captain and crew members. There was no fire observed on this ship, however, until approximately 6:00 P.M. of the 16th. It is not difficult to imagine that flames from the burning piers and warehouses spread to the *High Flyer,* reaching the cargo through the open hatchways. Sulphur in holds No. 2 and No. 4 (total 2000 tons) was observed burning about six o'clock. It was known that the ship had also been loaded with 860 tons of ammonium nitrate in hold No. 3. A call was made to Galveston at 8:00 P.M. for four tugs with oxy-acetylene cutting equipment and gas masks because authorities were apprehensive concerning the explosion potential in this second situation. The tugs arrived at Texas City between 11:00 and 11:20 P.M. Personnel boarded the

Los Angeles Fire Dept.—Capt. Conlin.

The remains of the *Keene* in the Main Slip. The *High Flyer* exploded as it lay against the *Keene,* having been blown across the slip from Pier "A" by the *Grandcamp* blast.

Los Angeles Fire Dept.—Capt. Conlin.

General view of wreckage on Pier A, showing remains of the fire-resistive warehouse. In center, wreckage is former Pier "O," and note that outer end is under water. Seatrain crane marks edge of Monsanto property. The *Grandcamp* was docked in slip next to Pier "O."

High Flyer and made several attempts to cut the anchor chain (finally succeeding) and to move the vessel. The latter effort could not be accomplished because tow lines failed, the two vessels were jammed and fouled, and the smoke, fire, and sulphur fumes had become so heavy that the area had to be evacuated. White smoke was observed about this time issuing from the No. 3 hatch. Efforts were abandoned to tow the vessel from the slip at 12:55 A.M. on the morning of the 17th.

The Second Explosion.

The *High Flyer* exploded at 1:10 A.M. As far as can be accurately determined, only one additional life was lost due to this second explosion.

The *High Flyer* like the *Grandcamp,* completely disintegrated. That portion of the *Wilson B. Keene* abaft No. 2 hatch was also destroyed. The wrecked and remaining forward portion of the *Keene,* which had a cargo consisting only of 445 tons of flour, may be seen in the photographs.

Missiles were again hurled through the air for thousands of feet. Testimony by eye-witnesses verifies that exceedingly high temperatures had been reached, as some of the pieces of metal observed in the air were "red hot," resembling a fireworks display. Large sections observed on the ground similarly showed the effects of tremendous heat and were warped and twisted into grotesque shapes. It was the missiles from the *High Flyer* which caused the severe damage and fires in the oil tank farms in the Humble and Richardson areas south of the main Terminal facilities.

Concussion forces were again severe. Reinforced concrete Warehouses A and B were reduced to rubble, except a small portion of Warehouse B on the shore end, which remained standing. Warehouses C, D, and E (unprotected steel) were collapsed further, original damage having been from fires started by the *Grandcamp* explosion and from exposure to the oil fires burning along the water front. A structural steel grain conveyor which connected the reinforced concrete grain elevator with Warehouse B (over the roof) was collapsed. Other buildings in the Terminal area, damaged by the first explosion, were demolished by the second.

Fires After Second Explosion.

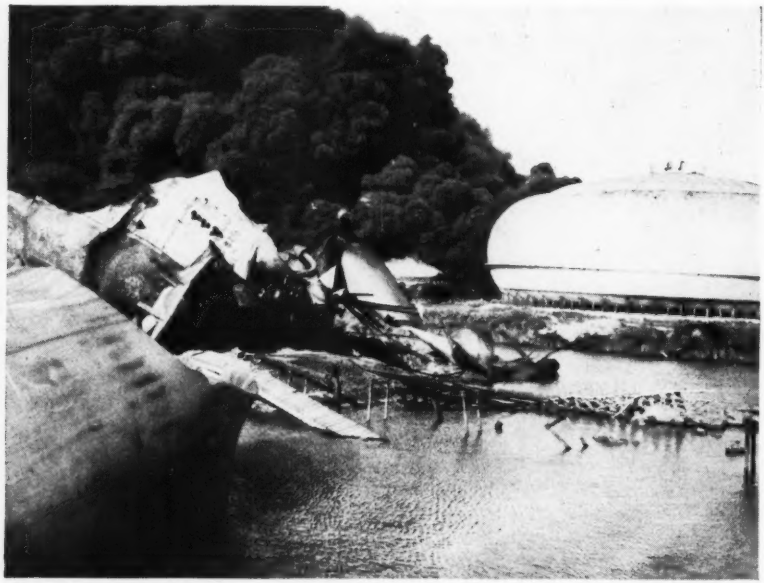
Fires gained impetus in the Terminal area following the *High Flyer* explosion, but the most sensational new fires occurred in the oil tank farm areas. In the Humble

Pipe Line Co. property four tanks were ignited immediately and four additional tanks fired from these exposure fires; in the Stone farm two more tanks were ignited; in the Republic Refinery one tank was ignited; while in the Carbide and Carbon Terminal property an aluminum tank containing isopropyl acetate and one steel tank burned.

All day during the 17th, rescue operations proceeded without measurable efforts at fire control. The ravished area was beyond salvage. Fires still burning in the Monsanto and Terminal Buildings slowed rescue workers and spread gradually among the rubble of twisted steel and flammable contents. The tanks were flaming torches and the crude oil fires burned with a black smoke which could be observed for miles around. A spectacular "boil over" occurred on the 19th, which is shown in the illustrations. Lack of water supplies in the Humble Company area prevented any attempt at fire control until the morning of the 20th, when a tank of bunker oil which burned slowly was extinguished with foam. Water was drafted from the South Slip for this purpose and foam powder brought from other refineries was used, as Humble's foam supplies had been ruined by heat.

Additional Rescue Work.

Cleaning up the debris-strewn area had to precede much of the rescue operations. Mayor Trahan of Texas City on the morning of April 17 appointed a special committee representing each of the industries affected to supervise relief and rescue operations under the direction of the chief engineer for the Pan American Refining Corporation. Governor Beauford Jester declared a "state of emergency" and designated the State Department of Public Safety to coordinate all police and rescue activities. There was some confusion of

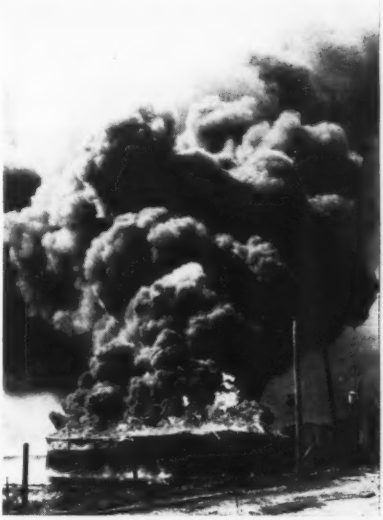


Los Angeles Fire Dept.—Capt. Conlin.

Wreckage in foreground was spheroid, similar to undamaged one at right. Smoke in background from fire on Humble Farm.

authority, but the emergency situation was so urgent that individual participants normally did the necessary without undue concern as to authorization. Army and civilian bulldozers, cranes, dump trucks and similar heavy duty equipment worked efficiently and speedily to remove wreckage so that buried bodies might be retrieved and the single access road cleared for use. Assistant Chief Dowdy was placed in charge of the remaining local volunteer firemen, who speedily received replacement apparatus from the War Assets Administration. Effective fire fighting in the Terminal area was not started, however, until the afternoon of the 18th, when Houston and Pasadena sent apparatus and manpower to the scene. Water was drafted from the slips, as the underground system still could not be used. The Coast Guard cutter *Iris* was used to pour water from the bay on the smoldering piers during the 18th. Isolated fires were still burning in the Monsanto property during the 18th also, a burning benzol tank providing the greatest volume of smoke. No fire fighting was attempted in this area and the flames only subsided as their fuel was consumed.

By the morning of the 19th, clean-up work had progressed admirably and fire fighting was systematic in the Terminal area. Most of the bodies that were to be located had been removed to mortuaries. The buildings in the city had been inspected and those unsafe were placarded.



Los Angeles Fire Dept.—Capt. Conlin.

One of the Humble Oil tanks burning two days after the explosion of the *High Flyer*. Ignition attributed to hot missiles.

III. Conclusions.

In a disaster of this nature and magnitude, evaluation of the principal contributing factors presents difficulties, but the following recommendations are offered for those who, in studying Texas City, desire to prevent similar disasters in their own communities:

(1) The "impossible" happened again at Texas City. Large fires and explosions continually emphasize the need for preparedness and throw the stigma of folly into the faces of those who repeatedly say: "It can't happen here."

(2) Prompt detection and reporting of fires remain the chief keys to control. (Delay in transmitting the alarm of fire on the *Grandcamp*, attempts to fight the fire without calling the fire department, and poor judgment in prohibiting the use of hose streams set the stage for the tragedy.)

(3) Chemical products must be continually analyzed to determine their fire and explosion hazards. Fire departments must search out chemical hazards within their protection zones. (The explosive violence of ammonium nitrate explosions was a matter of record, but even the experts erred somewhat in evaluating its hazards under fire conditions.)

(4) Special protection facilities required by the inherent nature of certain industrial enterprises must be provided to safeguard life and property which might be exposed. (The lack of readily available marine towing equipment, the lack of a port warden to govern handling of hazardous materials were serious deficiencies at Texas City.)

(5) More strict industrial zoning is obviously required, especially where an explosion

Los Angeles Fire Dept.—Capt. Conlin.

General view of damage in Monsanto plant. One of the 190 ft. distillation towers at right foreground, alkylation towers at rear, propane tanks in left center, and wreckage of low-pressure hydrocabon tanks in center foreground.

potential exists. (The 5000 employees of the concentrated industrial area surrounding the port facilities at Texas City were innocent victims in the disaster.)

(6) Dependence on established fire protection facilities in explosion hazardous areas is dangerous. (With the Terminal and Monsanto fire protection systems knocked out by the first blast, effective fire fighting was delayed (even after rescue operations had been essentially completed) because there was no organized plan to draft water from the bay and to utilize pumper equipment available.)

(7) Open areas between structures will mitigate explosion damage and are the only logical method other than subterranean construction. (The lessons at Texas City were similar to those of World War II in this respect. Reinforced concrete buildings within 200 feet of the explosions failed, while those 700 feet away were only damaged and did not collapse. Concussion forces were less severe on rounded surfaces and unencumbered structural steel.)

(8) Operational practices in industrial occupations established for convenience or utility but counterpoised to safety must be re-examined. (Disabling the *High Flyer* during loading of hazardous chemical was a serious act leading to the second fatal fire and explosion.)

(9) Proper storage of petroleum products remains of utmost importance. (At Texas City the installations were reasonably well planned and only about 22 per cent of the petroleum stored within a 1½-mile radius was lost by fire.)

(10) Port operational procedures and docking facilities require renewed fire safety analysis. Better supervision, increased protection facilities, and improved fire protection on shipboard are needed. (Texas City's disaster followed two ship fires and the Los Angeles explosion of June 22, 1947, is an indication that the end is not yet.)

(11) Most important, preplanning against disaster confusion incorporating regional fire defense organization is obligatory. (The lack of such planning was a severe handicap at Texas City, overcome only by individual initiative and personal heroism of those on the scene.)

IV. Losses.

On June 22, 1947, 67 days following the disaster, Texas City committed its 63 unknown dead to "God's gracious mercy and protection." These charred and broken bodies brought to 468 the known victims of the blasts. Over 100 others are still missing. The Red Cross reported 3000 injured, of whom more than 800

were hospitalized and 380 were still confined on June 1, 1947. Two thousand people were given shelter following the damages to homes in the city and 15,000 people were fed during the emergency period of several days.

Dollar losses are still indefinite and insurance claims not fully adjusted. Based on information available to the N.F.P.A. the following estimates are given below:

Property Damage		
Monsanto Chemical Company	$14,750,000	
Texas City Terminal Railway Co.	11,450,000	
Dwellings and contents, Texas City	2,500,000	
Mercantile, city, and school property, Texas City	2,000,000	
Marine hulls	1,500,000	
Humble Pipe Line Company	1,200,000	
Republic Refining Company	1,000,000	
Ludlow Manufacturing and Sales Co.	900,000	
Automobile (1100 cars) and aircraft (2)	750,000	
Slips and turning basin	600,000	
Railroad rolling stock	500,000	
Southport-Republic Terminal Co.	300,000	
Sid Richardson Refining Co.	300,000	
Pan-American Refining Co. (Oil Docks)	300,000	
Grain in elevator	300,000	
Carbide and Carbon Chemical Co. (Terminal tanks)	250,000	
Seatrain Lines (Loading crane)	200,000	
Sub-total		$38,800,000
Business Interruption, Debris Removal and Incidental Expenditures	$20,000,000	
Sub-total		$20,000,000
Life, Accident, Workmen's Compensation Insurance Loss Estimates		
Monsanto Company employees (Life and Workmen's Compensation Insurance estimate)	5,000,000	
Other life insurance estimated	2,000,000	
Other Workmen's Compensation Insurance estimated	1,000,000	
Texas City Volunteer Fire Department accident insurance estimate	75,000	
Other accident insurance estimate	125,000	
Sub-total		8,200,000
Total		$67,000,000

Los Angeles Fire Dept.—Capt. Conlin.

The steel barge which was carried 100 feet inshore by the displaced water in the slip where the *Grandcamp* exploded.

U. S. Army Air Forces.

View of Texas City Railroad Terminal property from an altitude of 5000 ft., taken two weeks after the disaster. (See other similar photos of oil tank farm areas and the Monsanto Plant.)

V. Details.

A. Texas City Terminal Railway Co.

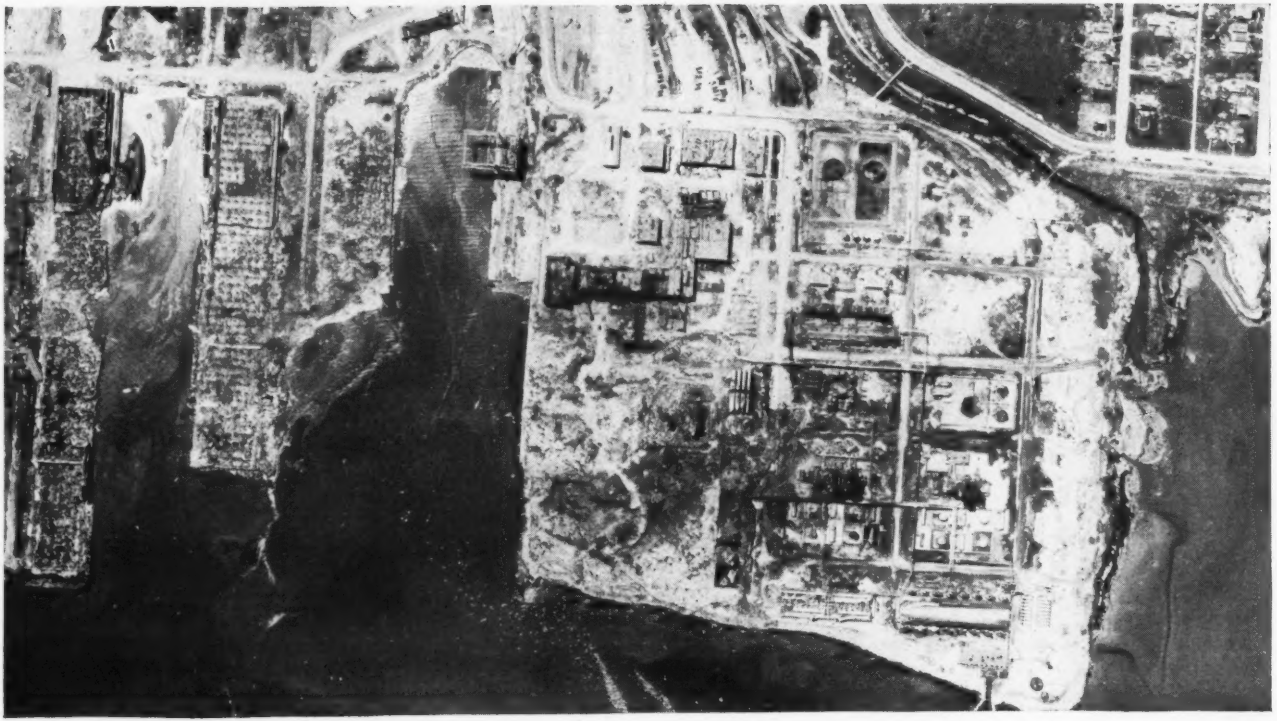
The Texas City Terminal Railway Company is jointly owned by the Santa Fe, Missouri-Kansas-Texas, and the Missouri Pacific Lines, and the Terminal is served by these railroads. The property was operated as a rail terminal and possessed warehouse and dock facilities. Pier and terminal warehouses data, given below, show that total floor area was 1,067,424 sq. ft. (about 24½ acres) under cover.

Other buildings included: (1) the idle compress building, built in 1915, which was a one-story, sprinklered frame structure, 22,610 sq. ft. in area and containing a small boiler plant; (2) the reinforced concrete grain elevator, 171 ft. high and the twelve adjoining reinforced concrete tanks 98 ft. high and 24 ft. in diameter, erected in 1910; (3) the one-story shop, generator and pump house of mixed construction erected during 1904-10; (4) the steel grain conveyor, 18 ft. wide and 790 ft. long, extending from the grain elevator to the roof (and 460 ft. along the roof) of Warehouse B, supported by steel frame-

Texas City Terminal Railway Warehouses.

Warehouse	Construction Features	Date Erected	Dimensions	Total Floor Area
0	Steel frame, sheet iron walls and roof. Two fire division walls. One story. Not sprinklered.	1914	155 ft. by 880 ft.	136,400 sq. ft.
A	Reinforced concrete. Two fire division walls. One story. Automatic sprinklers.	1912	155 ft. by 880 ft.	136,400 sq. ft.
B	Reinforced concrete. Three fire division walls. Two stories. Automatic sprinklers.	1929	120 ft. by 1160 ft.	278,400 sq. ft.
C	Steel frame, brick and metal walls, concrete tile on steel truss roof. Two fire walls. One story. Automatic sprinklers.	1910	100 ft. by 750 ft.	75,000 sq. ft.
D	Same as Whse. C except not sprinklered.	1911	100 ft. by 750 ft.	75,000 sq. ft.
E	Same as Whse. C except not sprinklered.	Uncertain	120 ft. by 520 ft.	62,400 sq. ft.
	Note — The above warehouses, located on the waterfront, stood on filled earth. Wharf aprons were 36 ft. to 72 ft. wide, uncovered, wood flooring on wood piling over water, except for partially covered apron along north side of Whse. B, which had concrete floor on wood girders and pilings.			
No. 1	Frame sidewalls with brick end walls, wood joist roof, 7 fire walls of 16 in. brick. One story. Automatic sprinklers.	1904	76 ft. by 1024 ft.	77,824 sq. ft.
No. 2	Steel frame and metal walls with tile on steel frame roof. One story. Not sprinklered.	1904	100 ft. by 250 ft.	25,000 sq. ft.
No. 3	Same as No. 2.	1904	100 ft. by 250 ft.	25,000 sq. ft.
No. 4	Same as No. 2.	1904	100 ft. by 250 ft.	25,000 sq. ft.
No. 5	Same as No. 2.	1904	100 ft. by 250 ft.	25,000 sq. ft.
No. 6	Wood frame (except one stone veneered end wall) with metal walls and roof. One story. One substandard division wall. Automatic sprinklers.	1904	90 ft. by 1400 ft.	126,000 sq. ft.
			Total	1,067,424 sq. ft.

View of Texas City Railroad Terminal property from an altitude of 5000 ft., taken two weeks after the disaster. (See other similar photos of farm areas and the Monsanto Plant.)



U. S. Army Air Forces.

Vertical photograph of the Monsanto plant and adjoining Terminal property two weeks after the explosion. This picture and other U. S. Army Air Forces photographs were taken to study the concussion damage effects and to compare them with bomb damage inflicted in Europe and Japan during World War II.

work (erected 1929); and (5) a locomotive shed of steel frame, metal-clad construction.

The oil piers were wood and extended 1032 ft. into the bay on wood piling. Smaller structures included a reinforced concrete grain dryer house (16 ft. by 26 ft.), a frame stucco dock superintendent's office (25 ft. by 80 ft.), another small office of frame construction near the elevator, two frame, metal-clad auto sheds, and miscellaneous small buildings.

Water supplies for fire protection consisted of one 100,000-gal. elevated (100 ft.) gravity tank which supplied the automatic sprinkler systems and the private hydrants (except that 8 hydrants near warehouses Nos. 2, 3, 4, 5 were fed from a second 100,000-gal. tank used principally for domestic purposes). The main fire service tank was supplied by a 600-gpm electric motor-driven service pump taking suction from a 300,000-gal. concrete reservoir, which was filled from two private wells having 230 and 240 gpm

Los Angeles Fire Dept.—Capt. Conlin.

View of reinforced concrete column failure in Warehouse "B."

capacity electric pumps. Secondary supplies were from two 1000-gpm electric fire pumps also taking suction from the reservoir. A good system of 6 and 8-in. mains supplied sprinkler systems and private hydrants. There was no connection to public water sources or mains. A total of 8850

NFPA.

Shows part of fire resistive Warehouse B, which remained upright.

sprinkler heads were installed in the protected buildings and pressure from primary supply was 42 lbs. on top line.

B. Monsanto Chemical Co.

This plant was built by the Defense Plant Corporation in 1942 to augment the supply of styrene in the wartime synthetic rubber program, at a cost of approximately $18,000,000. It was purchased by the Monsanto Chemical Co. in 1946 and was in operation at the time of the disaster, producing styrene and polystyrene plastic products.

Well laid out on a rectangular waterfront tract approximately 1300 ft. by 1450 ft. (43½ acres), the property was formerly occupied by a sugar refinery and some of the older utility and office structures were originally part of this enterprise. The construction was chiefly structural steel and masonry for major buildings and open steel framework for processing units. Spacing of structures was adequate for safety, and fire protection measures had been thoughtfully planned and executed. The severe damage done to the installation cannot be ascribed to any fail-

Forces photographs were taken to study the concussion damage effects and to compare them with those of World War II.

ure to provide adequate resistance or protection from explosion or fire, and, as a matter of judgment, it was obvious that even greater damages might have resulted had not construction and layout been superior. The fire protection provided was, nevertheless, rendered ineffective by the initial explosion.

Main Unit Groupings of Monsanto Structures.

Name	Damage*	Description
1. Polystyrene Building	Total C–F	A five-story masonry and steel structure (formerly the sugar house of the old sugar refinery) used in plastic production and for storage.
Adjoining Warehouses	Total C–F	Warehouses adjoining were one and two-story masonry and steel structures, the one story section extending along the waterfront. The latter building was only 300 ft. from the *Grandcamp*.
2. Steam Plant and Power House	Total C–F	One story masonry and steel building adjoining Polystyrene Building on the east, concrete stack. Building 500 feet from *Grandcamp*.
3. Office Building	Major C	Three-story masonry and steel with concrete roof and floors.
Service Building	Major C	Two-story masonry and steel with third story in process of construction.
Laboratory	Total C–F	One story, brick, wood joist.
4. Warehouse	Total C–F	One story masonry and steel directly behind Polystyrene Building.
Instrument Shop	Total C–F	One story, brick, wood joist also behind Polystyrene Building.
5. Ethylene Purification Units	Major to Light C–M–F	Two 60 ft. fractionating towers supported by steel framework, two heater buildings with steel framework and refractory heaters, six compressor units in a steel frame, asphalt protected, metal building, and a masonry and steel control house.
6. Alkylation Unit	Major except to tanks C–M–F	40 ft. unit supported by heavy structural steel framework with converter equipment reactors, and control house. Four 500-barrel storage tanks, one 250-barrel storage tank.
7. Distillation Units 1, 2	Towers: Unit 1, Major; Unit 2, Considerable; Unit 3, Slight. Towers withstood C, damaged by M and F. Control houses heavily damaged by C.	Two separate tower groups 190 ft. in height, each having two vacuum fractionating columns 165 ft. high, 10 ft. in diameter with six smaller towers, all embraced in steel framework. Each group has its own auxiliary equipment, control room, and horizontal tanks adjacent to the base of the tower. Piping considerable. Auxiliary equipment includes exchangers, pumps, and condensers.
8. Cracking Unit	C and M Moderate	Twenty low pressure, high temperature cracking units in structural steel framework, with control room of masonry construction.
9. Dehydrogenation Unit	C and M Light	A series of catalytic cracking furnaces and chambers and steam superheaters in steel framework with masonry enclosed control and instrument room.
10. Pump House	C—Heavy to building, light to contents	Brick-steel joist building housing nine sea water pumps for domestic use. Fire pump (1000 GPM steam unit) located in separate subterranean structure on harbor bank.

11.	Tankage† Benzol	Total C–F	Three 10,000-barrel tanks of benzol on east and north sides of area destroyed.
	Other Large Atmospheric Pressure Tanks	Total C–F	A total of 14 situated throughout the plant destroyed. Contained low pressure hydrocarbons.
	Propane Pressure Tanks	Light C	Eight tanks (510 barrels capacity each) on concrete pillars, containing propane, withstood blasts and exposure fires.
	Small Atmospheric Pressure Tanks	Varied Heavy to Light C–M–F	Approximately 25 tanks, horizontal and vertical types, located adjacent to processing units. Heaviest damage to 4 vertical tanks near Distillation Units.
12.	Fire Department and Foam House	Total C	Totally destroyed; buildings of light construction.

*C—Concussion Damages; F—Fire Damages; M—Missile Damages.
†See also Part C, this section, on major tankage.

C. Oil Tank Farms and Refineries.

The nearest refinery processing and service equipment within a mile and a half radius from the Texas City Terminal area was fortunately two-thirds of a mile distant. By virtue of this fact alone, the damage to the actual processing units of the Republic, Stone, and Richardson's Refining Companies was limited. Concussion damages in the Republic process area was the most severe of the three, but was not sufficient to halt operations. A missile from the *High Flyer,* weighing over a ton, virtually sliced the 2-story, brick, wood-joisted office building in half. Fortunately, vital and hazardous areas were not struck. The refinery area proper of the Stone Oil Company suffered serious damage only at one of the shell stills which was struck by a missile from the *Grandcamp* explosion, causing ignition of released vapors. This fire was extinguished before serious complications ensued. The Richardson refinery facilities sustained only superficial damage from the shock waves and missiles.

A summary of the petroleum tankage in the area and the damage sustained by fire is given below.

Approximations of Stocks in Tanks (10,000-barrel or Larger Capacity) and Their Fire Damages in the Farm and Refinery Areas Within 1½-mile Radius of Teminal.*

(Quantities expressed in 42-gal. barrels)

Type Hydrocarbon	Stock of Oil in Tanks on April 16th	No. of Tanks	Ignited Direct from Explosion Missiles: Stock Qty.	Ignited Direct from Explosion Missiles: No. Tanks	Ignited from Exposure Tank Fires: Stock Qty.	Ignited from Exposure Tank Fires: No. Tanks
Natural Gasoline (14 lb. and lighter)	12,500	4	None	None	None	None
Gasoline and Naphthas	293,000	24	3,400	2	None	None
Crude Oil	995,000	25	232,900	6	139,900	4
Kerosene and Gas Oil	431,250	26	None	None	5,600	1
Topped Crude and Miscellaneous Other	68,950	14	None	None	None	None
Residual Fuel Oil	23,000	4	None	None	None	None
Benzol, Other Aromatics	29,600	5	29,600	5	?	?
Total	1,853,300	102	265,900	13	145,500	5

*Figures secured from report by George Armistead, Jr. Smaller tanks (less than 10,000 barrels) not included.

U. S. Army Air Forces.

Aerial view of the Monsanto plant two weeks after the disaster. The *Grandcamp* exploded in the slip at the left. (See other similar photos of the Terminal and oil tank farm areas.)

Terminal and oil tank farm areas.)

U. S. Army Air Forces.

Aerial view of the oil tank farms. Note tanks burned out and those damaged by missiles and concussion. Refinery areas in background. (See other similar photos of Terminal and Monsanto plant.)

Several observations are in order concerning the statistics given above.

1. The total capacity of the 120 major tanks was 6,324,500 barrels, but 102 of these were only 29 per cent full (1,853,300 barrels) on the day of the explosion.

2. On the basis of stock susceptible to fire loss in these tanks (1,853,300 barrels), only 22 per cent burned (411,400 barrels).

3. On the basis of total major tanks subject (120), only 15 per cent (18) were ignited by either direct blast damage or exposure.

4. Of the 18 major tanks which ignited, 8 were directly ignited following the *Grandcamp* explosion, 6 following the *High Flyer* blast, and 4 additional due to exposure conditions after the second blast.

5. The high loss of crude oil was principally caused by the burning of the 8 tanks in the Humble area where tankage was over 50 per cent full, and 80 per cent of this fuel was burned.

6. The losses of low-flash point fuels were low (except for benzol), principally because of distance factors. Benzol losses were high because of their close proximity to the blasts and it is reasonable that any other flammable liquid in those tanks would have been ignited. There is little relation, therefore, between relative flammability and losses; it is obvious instead, that location and the missile trajectories influenced losses.

NFPA.

Fire-resistive grain elevator on the Terminal property (damaged more than photo illustrates) and collapsed conveyor.

NFPA.

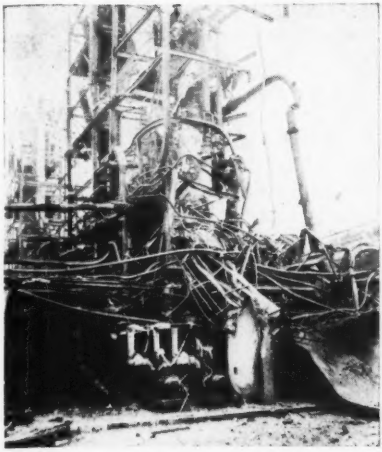
This photo was taken within seconds of a boilover in a crude oil tank in the Humble Tank Farm. This ignited a tank of bunker oil previously not involved.

Other interesting factors concerning the oil tank fires can be briefly mentioned:

1. The damage of the oil facilities was of three types:

(a) Concussion: tank roofs of wood or sheet steel were pushed down (rafters and other supports failing through overload) and shells of empty tanks were dented, but forces applied horizontally were not sufficient to cause collapse.

(b) Missiles: hot and cold missiles, weighing from a few ounces to nearly 100 tons, fell in farm areas. In nearby areas, trajectories were flat, increasing toward the vertical as range increased. At 2½ miles the missiles fell almost vertically. Tank roofs, thin-walled pipes, upper shell courses of large tanks were perforated. Few missiles striking tanks on a horizontal plane had sufficient force to pierce tank



NFPA.

Wreckage of piping at base of ethylene purification fractionation towers in Monsanto plant.

shells. Where explosive mixtures existed, explosions resulted, followed by fire.

(c) Fires: most of the fires are believed to have been caused by heated missiles (above ignition temperature of flammable liquid vapors) especially in nearby Terminal farm areas (and in the Monsanto plant). This is supported by the fact that only hot missiles could have ignited wooden wharf planking, wood roofing of tanks, and pile clusters in the surrounding regions. Evidence also supports the theory that hot missiles were in greater abundance following the *High Flyer* blast and more fires in nearby farm areas resulted from this explosion than from the *Grandcamp*. (It will be remembered that the fire is known to have burned for seven hours before the *High Flyer* blast and only one hour prior to the *Grandcamp* explosion. This would result in high temperatures developing in the former case. Also the fire is known to have involved several holds on the *Flyer* rather than No. 4 only on the *Grandcamp*.)

2. Whether tank roofs were blown off or collapsed inside following a considerable period of burning was influenced by the force of gas explosions which, in turn, was influenced by the volume of liquid in the tank at time of ignition. The higher percentage of volume of liquid, the less the violence of the gas expansion.

3. Boilover occurred in one observed case in the Humble Farm, resulting in the spread of fire from a tank of crude oil to a large tank containing bunker oil which otherwise would not have been partially lost. (The bunker tank was subsequently extinguished.)

4. Several "empty" tanks were exploded by hot missiles or friction sparks. Fragmentation from these detonations was not serious, few portions being carried beyond dikes.

5. Where inadequate vents were provided, tanks subject to heat from fires were distorted from internal pressures. In the Carbide and Carbon Chemical Co. tank area this was particularly noticeable. An aluminum tank containing isopropyl acetate (flash point 40° F.) burned and melted to the ground, presumably due to the lack of a flash arrester. Adjacent tanks, including three identical aluminum tanks, were distorted as well as lifted from their foundations.

NFPA.

Failure of brick wall in Monsanto Pump House.

D. City of Texas City.

The closest dwelling properties were approximately a half mile from the core of the explosion. Such segregation was indeed fortunate for, while the damages sustained were serious, the distance factor must be looked upon as a mitigating element. Other cities are not so fortunately zoned.

Frame bungalow type, single and double family structures were severely battered, many totally collapsing, in an area roughly ½ mile from the Terminal docks. This heaviest damage included approximately 12 blocks, which contained perhaps 150 homes. Beyond this area and within a radius of a mile, damage to dwellings was chiefly to roofs, windows, and porches, although many were so struck by the concussion waves that they were rendered unsafe for occupancy. Walls shifting off their foundations and thrown out of alignment were chiefly responsible. Beyond the mile radius and up to approximately 1½ miles, window glass damage was extensive and some missiles pierced roofs.

Concussion damage in the closer building was too complete to determine how the forces were applied, but in those some distance away evidence showed downward pressure zones formed a decided pattern, while even farther from the source of the blast, the negative pressure effect (uplifting of roofs) was readily discernible.

The school building was located about a mile from the Terminal. Damage to this 2-story structure was of interest, as every partition inside was destroyed, while the brick exterior walls were not damaged. The school was in session and while many children were injured, none were killed, and teachers evacuated the children from the building and the area promptly.

In the mercantile district many buildings of brick wood-joist, brick veneer, and stucco construction were heavily damaged, the higher buildings and those of largest area suffering the greatest loss. Two theatres suffered roof collapse, while several 2-story mercantiles had similar damage. Plate glass loss was extremely heavy throughout the business district.

In a survey of all dwelling and business buildings, 539 were condemned as unsafe out of a total of 1500 inspected.

E. Miscellaneous Properties Involved.

1. The Vessels.

The S. S. *Grandcamp* (French Line) totally disintegrated from the explosion. The ship was built in 1942 and was formerly the S. S. *Benjamin R. Curtis.* A Liberty type, the vessel was 422 ft. long,

Los Angeles Fire Dept.—Capt. Conlin.

Damage to dwellings in the residential area of Texas City over a mile from the explosions.

had a gross tonnage of 7176, and had 5 cargo hatches. Cargo on board the vessel included 2339.69 tons of ammonium nitrate, 380 bales of cotton, 16 cases of ammunition and unknown quantities of binder twine, tobacco, shelled peanuts, machinery and drill stem.

The S. S. *High Flyer* (Lykes Bros. Steamship Co., Inc.) also totally disintegrated from the explosion aboard that vessel. The ship was built in 1944 and was a C-2 type, with a length of 438 ft. and a gross tonnage of 6214. There were five cargo hatches and, at the time of the explosion, contained 961 tons of ammonium nitrate, 871 tons of knocked down box cars and 2000 tons of sulphur.

The S. S. *Wilson B. Keene* (Lykes Bros. Steamship Co., Inc.), is considered a total loss, although the bow portion remained visible. This vessel was a Liberty ship of the same type as the S. S. *Grandcamp* and had a cargo of 445 tons of flour when the explosion occurred.

2. The Turning Basin and Slips.

Major obstructions in the turning basin were removed by the Corps of Engineers at an estimated cost of $15,000. The largest item removed was a 35-ton portion of a ship's hull, undoubtedly from the *High Flyer*. Other pieces of bent, twisted and ragged steel plate weighing from 13 tons to ½ ton were lifted from the basin at points up to 600 feet off the bay end of "Pier" B, where the average depth is 35 ft.

Soundings taken in the main slip beneath the *High Flyer* anchorage reveal a crater 63 ft. deep. The pre-explosion depth was 34 feet, with the last previous dredging completed in December, 1946. No unexploded ammonium nitrate could be found in this slip following several days of exploration by a diver. Soundings taken in the North Slip when the *Grandcamp* exploded did not reveal any substantial crater; rather soundings showed a depth of only 20-25 ft. in a position near the stern and 30-33 ft. at the bow end. (Hold No. 4 where explosion occurred was aft of midship house.) The difference is accountable due to the lifting of the water in this slip and its resettling plus the destruction of the earth foundation of "Pier O."

3. Oil Shipping Facilities.

Almost all of the waterfront area was arranged for bulk shipment and receipt of petroleum except on "Pier O," where the *Grandcamp* was docked. Extensive pipe lines to tanker loading and unloading berths fronted at "Piers" C and D. Wood piling supported the piping at this location. Fire caused extensive damage in this area, but it could not be determined what precise sequence of events preceded their outbreaks. It is known that missile damage on some pipes released oil, which was subsequently ignited and undoubtedly contributed to the extensive damage to these facilities. The oil dock equipment at the South Slip was almost totally ruined.

The well-segregated oil shipping units of the Pan American Refining Corporation below the South Slip and facing on the channel were comparatively undamaged. A few small fires in this area destroyed approaches and are believed to have originated from burning oil on the water's surface from spills in the South Slip's facilities.

4. Seatrain Loading Crane.

Damage to this installation was caused by flying missiles which struck the steel supporting legs with such force as to bend main members, throwing the structure out of alignment.

5. Molasses Terminal.

Three tanks, located in a group directly opposite "Pier O" were collapsed by the concussion. One of these had a capacity about 10,000 barrels, while the other two were 2000 barrel size. Small wooden buildings were also collapsed. There was no fire observed in this area.

6. Roadways.

Only a single access road serviced the Terminal area. This road passed directly in front of "Piers" and the North and Main slips. The explosion of the *Grandcamp* caused the barge *Leghorn II* to be cast across this roadway and littered the area with heavy debris which made it unusable for traffic. The collapse of the grain conveyor from the *High Flyer* blast similarly cut the road to traffic and again cast heavy steel objects across the single artery. The effects of this damage handicapped rescue activity measurably. Bay St. and South St. in the town were also badly pock-marked and caved by heavy missiles.

7. Railroad Rolling Stock.

A survey showed that 360 freight cars (mostly of the box car type) were destroyed or heavily damaged. Many contained flour and were ignited by hot missiles which penetrated roofs or caught fire from adjacent burning structures.

8. Automobiles and Aircraft.

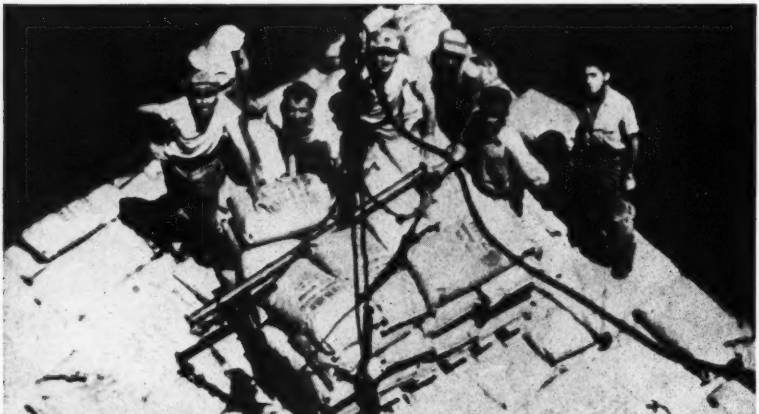
No accurate count of the number of automobiles destroyed is available, but estimates run to 1100. Most of these belonged to employees working in the immediate vicinity and to those curious people who came to the dock area to witness the pre-explosion fire on the *Grandcamp*. In addition, the Texas City fire department trucks, cars belonging to volunteer members and a host of other vehicles in the area at the time of the *High Flyer* blast were wrecked. Two aircraft were destroyed by the concussion waves as they flew over the terminal when the first ship exploded.

F. The Ammonium Nitrate Fertilizer.

1. Production.

The ammonium nitrate fertilizer involved at Texas City was produced at the Iowa Ordnance Plant, Burlington, Iowa; the Cornhuskers Ordnance Plant, Coplant, Nebraska; and the Nebraska Ordnance Plant, Wahoo, Nebraska. These facilities are operated on a contracting basis by the Emergency Export Corporation for the Ordnance Department, United States Army.

Basically the production techniques followed at these facilities, which are actually graining plants, are to process ammonium



Bureau of Mines.

Showing method of loading ammonium nitrate fertilizer aboard ship. Note 100 lb. paper bags and concentrated piling. Broken bags are visible in original print in left foreground.

nitrate liquor received in tank cars by:

(1) lancing (to dissolve the crystallized ammonium nitrate); (2) evaporating — maximum temperature allowable, 325° F. (to change the liquor to a molten form); (3) graining (to provide proper granulation); (4) waxing (to minimize moisture absorption by the granules); (5) adding clay (to assist in providing a free flowing product); (6) bagging. The finished product is required to meet the following government specifications:

Moisture content	0.25% maximum
Ether soluble material (wax)	0.75%±0.35%
Water insoluble material (clay)	3.50%±1.00%
Total nitrogen	32.50% minimum

Granulation specifications called for require 100 per cent minimum pass through a U. S. Standard No. 8 sieve, 55 per cent minimum through a No. 35, and 8 per cent maximum through a No. 100 sieve. The ammonium nitrate liquor used was also governed by strict government specifications as follows:

Ammonium nitrate, minimum	70.0%
Acidity	None
Alkalinity, maximum	0.05%
Phenol	None
Nitrites	None
Ether soluble material, maximum	0.10%
Water-insoluble material, maximum	0.30%
Ferrocyanides, maximum	0.10%
Pyridine, maximum	0.005%
Thiocyanates, maximum	0.01%
Sulphates, maximum	0.50%
Chlorides, maximum	1.50%

The wax used was purchased from a single company and had the following manufacturers' specifications:

Hydrometer indication at 160° F. (API)	43-46
Flash point (ASTM D92-46)	470°-490° F.
Fire point (ASTM D92-46)	540°-560° F.
Viscosity, S.U. at 210° F. (ASTM D88-44)	47-50
Oil content (ASTM D721-44)	11-14%
Melting point (ASTM D87-42)	139°-145° F.
Penetration, needle (ASTM D5-25)	50-70
Color	Brown

All the plants used a kaolin-type clay which contained less than 1 per cent moisture and was ground so that 97 per cent would pass a 200-mesh sieve.

It may be observed from this information that the material was of standard grade and tests of samples of all the boxcar lots shipped to Texas City failed to reveal any decomposition or chemical changes in the material. These tests were conducted by the Emergency Export Corp. and the Bureau of Explosives, Association of American Railroads. The processes at each plant were examined by chemical engineers of the U. S. Bureau of Mines and it appeared unlikely that any materials other than normal constituents could have been incorporated in the product.

The only observations of possible significance to the fires and explosions at Texas City with regard to the manufacture processes employed are:

1. The paraffin wax was in direct contact with the ammonium nitrate, a strong oxidizing agent. Under conditions of high heat (as by fire), chemical reactions which would be self-sustaining would result between the two materials.

2. The paper bagging was a readily ignitable material and tests on small samples filled with the fertilizer showed that it would ignite when subject to a heat of 300° F. for five or six hours. A steampipe would provide this much heat under certain conditions. The bagging when *not* filled with fertilizer did not ignite in similar tests.

3. The multi-walled paper bags were so constructed that the second sheets from the outside and inside were impregnated with an asphaltic material to provide moisture resistance. This material would increase the heat of combustion.

4. The labeling on the bags gave no indication that the material was hazardous and did not conform strictly to regulations in that the name "Fertilizer" preceded the designation "Ammonium Nitrate," instead of vice versa.

Bureau of Mines.

Stowage of ammonium nitrate fertilizer in ship's hold, showing cargo battens.

5. The material, being in a fine granular form, could easily escape from the bagging if the latter was damaged.

2. Handling.

The ammonium nitrate fertilizer was shipped to Texas City via rail on government bills of lading designated as "Fertilizer Compound (Manufactured fertilizer) NOIBN, Dry, in paper bags (Fertilizer grade Ammonium Nitrate)." (NOIBN stands for "not otherwise indexed by name.") The material was consigned to the "French Supply Council, Transit Division" and was stored in Warehouse O pending shipment abroad.

Loading on the *Grandcamp* was accomplished by stevedores who apparently had no specialized knowledge of the fire and explosion hazards of the material. Crew members of the *Grandcamp* who survived (seven out of the total complement of 41) similarly displayed ignorance of the hazards of ammonium nitrate fertilizer. All those who testified at the official U. S. Coast Guard inquiry also showed a lack of knowledge of the regulations governing handling of the material as published by the Bureau of Marine Inspection and Navigation, U. S. Department of Commerce and the U. S. Coast Guard. These rules are contained in "Regulations Governing Explosives and Other Dangerous Articles on Board Vessels" and are dated April 9, 1941. The essential provisions of these regulations as affect ammonium nitrate, follow, with indications of compliance or non-compliance in the cases of the two Texas City explosions:

Regulations	Compliance—Texas City
1. The substance shall not be stowed in the same compartment or hold:	
(a) In which explosives are stowed.	No violations (small arms ammunition in separate hold on the *Grandcamp*)
(b) In which acids or other corrosive liquids are stowed, all chlorates and other nitrates.	No violation
(c) In which flammable liquids are stowed.	No violation
(d) In which cotton, sulphur in bulk, or charcoal are stowed.	No violation
2. The substance shall not be stowed in a hold over or under one in which sulphur in bulk is stowed.	No violation (sulphur in separate hold on the *High Flyer*)
3. The substance shall not be stowed in proximity to readily combustible materials such as textile products.	No violation
4. All containers shall be tight; no leaking or sifting containers or containers that give evidence of leaking or sifting shall be placed on board the vessel.	Violation
5. Shipper is required to give written notification in advance to the vessel regarding the characteristics of a dangerous cargo.	Violation
6. No smoking during loading operations.	Violation

The three specific violations are cited as contributing factors to the fires and explosions aboard the *Grandcamp* and *High Flyer*.

3. Characteristics Following Ignition.

Ammonium nitrate, like any nitrate, supplies oxygen when heated and thus possesses hazardous qualities when viewed from the fire propagation and explosion potential viewpoints. Decomposition of ammonium nitrate into ammonia and

nitric acid is rapid above 176° F. ($NH_4NO_3 \rightarrow HNO_3 + NH_3$). Nitric acid acting on organic material releases oxygen to form nitrous acid and then in succession nitrogen, water and nitrogen tetroxide, an even more vigorous oxidizing reagent. The reactions and reversible reactions of the decomposition products are too complex chemically for detailed explanation in this article. It is significant, however, that they are accompanied by exothermic heats which quickly bring about an explosion potential. Other factors (besides temperature), affecting explosion hazard and remarks concerning their part in the disaster are listed:

Factors Favoring Explosion Under Fire Conditions	Remarks
1. Strength of detonation impulse — the greater the impulse the greater the explosion hazard.	No pre-explosion detonation impulses at Texas City.
2. Density of stowage— the higher the density the more violent the explosion.	High densities present in holds of both ships.
3. Packaging—loose material which is subject to greater contamination increases explosion potential.	Paper bag breakage noted at Texas City.
4. Particle size — the smaller the particles the greater the explosion hazard.	Granulation according to Government specifications.
5. Moisture content—the lower the moisture content, the greater the explosion hazard.	Dry, unseasonably cool weather on April 16, 17, with 20 MPH, NNW wind.
6. Impurities — acids, oxidizable materials, organic materials increase explosion hazard while alkali or alkaline earth tend to de-sensitize.	No known impurities. Paraffin wax coating and asphaltic bag coating only possibilities known.

Ammonium nitrate will propagate its own explosion wave. Under conditions as at Texas City where the high concentrations of small grain, treated fertilizer were stowed within the confined space in the holds of ships and subject to fires, the intense heat of decomposition could logically be expected to cause a violent explosive reaction. It may be stated conclusively that fires caused the explosions and that they occurred without an impact force or detonator. What caused the fire in the *Grandcamp* will never be known with certainty. It reasonably could have originated from nothing more spectacular than a carelessly discarded cigarette or match or possibly ignition of bagging following prolonged exposure (five or six hours perhaps) to steam pipes reaching a heat of approximately 300° F. The fire on the *High Flyer* was caused by exposure conditions and most probably could have been prevented if the ship had been withdrawn from the danger area during the nine-hour period between the first explosion (9:12 A.M.) and the first indication of fire on the *High Flyer* (about 6:00 P.M.) or even later (prior to 1:10 A.M.) if fire-fighting facilities had been available and properly utilized.

4. Explosion Prevention Practices.

It would be good practice to adopt the following precautions to prevent another disaster involving ammonium nitrate fertilizers:

1. Exercise strict control over purity at point of manufacture to prevent contamination with acids, oxidizable, organic (carbonaceous) materials.
2. In mixed fertilizers (*i.e.*, superphosphates, ammonium nitrate, and organic meals), neutralization will be required to avoid hazard of spontaneous ignition. (Treatment of the superphosphate with ammonia has been successful if applied properly.)
3. Storage of the material in warehouses or stowage on ships should follow present requirements — segregation from organic, acidic, oxidizable, highly combustible or explosive materials and storage in separate fire areas from large concentrations of ordinary combustible materials. In addition, ventilation, limitation of amounts stored in a single area and accessibility for fire fighting should be considered. Automatic sprinkler protection is recommended for all storage warehouses handling the material. Storage should maintain safe clearance from steam lines and electrical wiring.
4. Handling in transit requires the same pre-

Los Angeles Fire Dept.—Capt. Conlin.

Wreckage in foreground is former one-story warehouse of the Monsanto Chemical Company, in left center, the former steam plant and power house, and in background, the polystyrene building.

cautions against contamination as in storage.

5. Packaging should be in metal drums or tight wooden casks to prevent accidental spillage. Any drums or casks split or broken in handling or storage should be removed and spillage disposed of immediately in a safe manner.
6. Labeling requirements should include markings in conformance with standards presently recommended for oxidizing materials, indicating the hazardous properties of the chemical.
7. Detonators should not be used to break up caked materials.
8. Strict no smoking rules should be enforced during storage and handling, and the use of any open flame devices prohibited.

5. Fire Fighting Operations.

In case of fire, immediate application of water in large quantities is probably the best procedure, even though a large water loss may result, as the ammonium nitrate is highly soluble in water. As ammonium nitrate is dissolved in water a cooling effect is produced (unlike many chemicals which produce heat when dissolving in water).

Carbon dioxide, foam and other extinguishment agents of the smothering type are ineffective, because ammonium nitrate provides its own oxygen for combustion. Steam is of no value whatsoever.

As in the case of any nitrate fire of major proportions, caution should be used in applying hose streams, as the sudden formation of steam may cause minor explosions which will scatter the burning material. Nevertheless, hose streams, applied from a considerable distance or from behind some barricade, apparently are the only practical method of fighting such a fire.

Automatic sprinkler protection for buildings where ammonium nitrate is stored is highly desirable, as it provides prompt application of water in case of fire without exposing fire fighters to personal danger. However, as in the case of any commodity, the nitrate should be placed in piles of moderate size and height to permit effective action by the sprinklers.

Gas masks should be worn by fire fighters, as the oxides of nitrogen are toxic.

6. Previous Major Fires and Explosions.

1906, Witten, Germany: Explosion involving ammonium nitrate, TNT, and potassium nitrate. Cause unknown.

January 14, 1916, Gibbstown, N. J.: Explosion of concentrate solution of ammonium nitrate during crystallization.

July 30, 1916, Wurgendorf, Germany: Explosion of compound 80% ammonium nitrate, 12% TNT and 4% nitroglycerin and grain mill. Sun on metal drums caused decomposition.

September 15, 1916, Oakdale, N. J.: Explosion during manufacture of ammonium nitrate in crystallizing pans.

October 4, 1918, Morgan, N. J.: Explosion of 9,000,000 pounds of pure ammonium nitrate and 12,000,000 pounds of amatol (a mixture of 80% ammonium nitrate and 20% TNT). Fire believed responsible for causing explosions.

April 12, 1920, Stolberg, Germany: Explosion of mixture of ammonium nitrate, powdered aluminum and TNT being converted from an explosive into fertilizer. Material had caked and explosion resulted from attempts to break up mass.

April 19, 1920, Brooklyn, N. Y.: Steamer *Hallfried*—chlorate fire involved 8460 casks containing 4,230,000 pounds of ammonium nitrate. Approximately 3900 casks burned. Minor explosions but none severe enough to cause ship to disintegrate.

April 26, 1921, Kriewold, Germany: Explosion of ammonium nitrate in two railroad cars believed caused by attempts to blast caked mass. 19 persons killed.

September 21, 1921, Oppau, Germany: Explosion of 5000 short tons of ammonium nitrate and ammonium sulfate following dynamite blasting of caked materials. 586 killed, 1952 injured, and 2138 buildings destroyed.

April 4, May 3, 1925, Muscle Shoals, Alabama: Two separate fires involving railroad cars containing ammonium nitrate in wooden barrels. No report of explosion.

May 7, 1925, Emporium, Pennsylvania: Explosion in an evaporating pan during reprocessing One killed.

VI. References.

Special acknowledgment and thanks are expressed to the following individuals who contributed in a personal way to the N.F.P.A. investigation of this disaster:

Aaron, Sergeant, Houston Police Dept.
Boone, Henry R., Capt., Los Angeles Fire Dept.
Braidech, M. M., National Board of Fire Underwriters.

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Conlin, C. A., Jr., Capt., Los Angeles Fire Dept.
Davis, H. H., Fire Prevention and Engineering Bureau of Texas.
Ferguson, C. W., Oil Insurance Assn. of Texas.
Gross, Harry, Capt., Los Angeles Fire Dept.
Hanson, R. J., M.I.T.
Higbee, F. D., Warden, Port of Los Angeles.
Keepers, Hugh V., Fire Prevention and Engineering Bureau of Texas.
Richardson, G. W., Acting Chief, Houston Fire Dept.
Whittlesey, Roy E., Chief, Houston Fire Dept.

Special credits are given to the following sources of information (other than previous N.F.P.A. publications) which have been used in compiling this report:

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In addition, letters from the following individuals are acknowledged:

Armistead, George, Jr., Washington, D. C.
Booker, H. K., North American Cyanamid, Ltd.
Boone, Henry R., City of Los Angeles, Department of Fire.
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Christensen, B. T., Chief Chemist, Emergency Export Corporation.
Comegys, C. N., Oil Insurance Association.
Conlin, C. A., Jr., Capt., City of Los Angeles, Department of Fire.
Culberson, Olen, Railroad Commission of Texas.
Davis, H. H., Fire Prevention and Engineering Bureau of Texas.
Davis, R. O. E., U. S. Department of Agriculture, Agricultural Research Administration.
Fisher, P. L., Carbide and Carbon Chemicals Corporation.
Gross, Harry, City of Los Angeles, Department of Fire.
Heagy, Kenneth, Corps of Engineers, Galveston, Texas.
Holman, J. L., Brig. Gen., Office of the Chief of Ordnance, War Department.
Holt, I. M., United States Maritime Commission.
Hussey, G. F., Vice Admiral, Bureau of Ordnance, Navy Department.
Huston, W. E., Republic Oil Refining Company.
James, Garrett B., Sr., NFPA Committee on Hazardous Chemicals and Explosives.

Keepers, Hugh V., Fire Prevention and Engineering Bureau of Texas.
Kersten, F. C., Field Director of Ammunition Plants, Office of the Chief of Ordnance.
Krallman, J. H., Cardox Corporation.
Lindsey, Roy H., Stone Oil Company.
Mills, S. N., Interstate Commerce Commission.
Murph, D. S., The National Fertilizer Association.
Nuckolls, Asa H., Consulting Chemical Engineer, Chicago 11, Illinois.
Pfeiffer, J. L., Capt., Headquarters Army Ground Forces.
Prussing, George F., Western Oil and Gas Association.
Sayers, R. R., Bureau of Mines, U. S. Department of the Interior.
Sefranka, R. M., Lt., Cornhusker Ordnance Plant.
Shepheard, H. C., United States Coast Guard.
Starr, Donald F., Mayor, Nebraska Ordnance Plant.
Trahan, J. C., Mayor, Texas City, Texas.
Wainwright, J. M., Gen., Commanding, Headquarters Fourth Army.
Wood, J. H., Jr., Atlantic Pipe Line Company.
Yocum, G. A., Monsanto Chemical Company.

Previous N.F.P.A. publications given for reference include:

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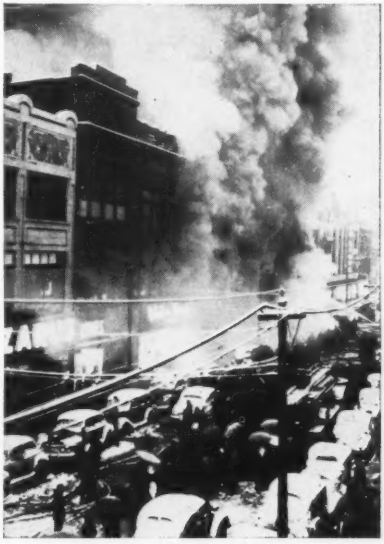
Recent Fires

The following summaries of large loss fires reported to the NFPA during the second quarter of 1947 are presented as typical of the current loss experience. They represent only a small fraction of the important fires that have occurred during this period.

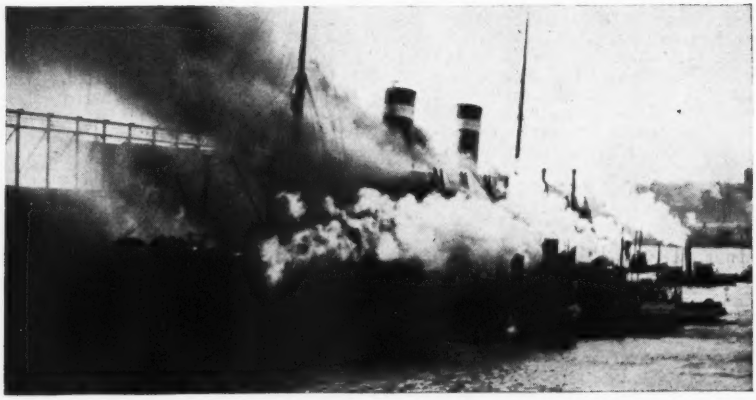
March 2, Wilkes-Barre, Pa. Multiple Occupancy—Mercantile:

The alarm of fire was given by the occupants of a third floor apartment at 4:07 on a Sunday afternoon. The fire originated in the basement stock room of the Neisner Bros. store. It is obvious, therefore, that detection was seriously delayed. This fact was verified when fire fighters reaching the scene were presented with a completely smoke-charged structure. This situation was one which could have been avoided through the use of automatic sprinklers or automatic fire detection equipment in the basement area. Without such facilities the fire caused: (1) the death of one fireman from a heart attack and injury to 15 others; (2) the rescue of 5 women from third floor windows by ladders; (3) the spread of fire from the building of origin to 3 adjoining and communicating structures and smoke damage to several others; (4) heavy fire loss to 9 mercantile stores, including Neisner's and a Whalen's Drug Store, and smoke damage to an A. S. Beck shoe store, a McCrory outlet, a Lerner's shop, Lobel's Youth Center and the Lazarus Dept. Store. Investigation of contributing factors reveals that construction deficiencies played a major role in the fire. The building of origin was a 3-story, brick, wood-joisted structure, and despite enclosed stairwells, hollow spaces in the walls permitted flames to travel vertically and break out on each of the floors above. Wood floor joists were common to the adjoining structures,



Acme.

Wilkes-Barre, Pa., fire, March 2.



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Fireboats pour water into the S.S. *John Ericsson*, berthed at a New York pier, on March 7. Formerly the luxury liner *Kungsholm*, the ship carried troops during the war. The loss, not covered by insurance, may run to $775,000, and it is doubtful that the ship will ever be used again for transoceanic service.

and there were no intervening fire walls. Basement openings to adjoining mercantile establishments were also contributing factors to the spread because they lacked fire door protection. Fire-fighting efforts were successful in that they saved the entire block from destruction. Eight pumpers, 5 hose wagons, 4 ladder trucks, plus supplemental units, were employed, as a general alarm brought all reserves and summoned aid from 7 nearby departments. Twenty-one 2½-in. hose lines and an equal number of smaller lines were used to flood the fire area from front and rear, from roofs of adjoining buildings, and from inside affected structures. Loss: Building, $289,000 (value $930,000); contents, $544,000 (value $830,000); total, $833,000.

March 3, near Vernon, B. C. Army Warehouse and Workshop:

A noontime fire swept a large T-shaped area, one-story, frame warehouse and workshop of the Royal Canadian Engineers, causing total loss to structure and contents. The fire, believed caused by a carelessly discarded cigarette, started in a washroom and had made substantial headway in the unsprinklered building before being discovered by a workman returning from lunch. A reduced Army fire department (one 600-gpm pumper with 4 men) was summoned at 12:55 P.M., but was unable to cope with the rapidly spreading flames. Successful attempts to remove several vehicles from the building through a large door opening had the adverse effect of spreading the fire through the creation of drafts. The Vernon Fire Department was not called until 1:05 P.M. Their response with one 750 gpm pumper and 29 men was thus delayed to a degree which nullified their effectiveness except for such aid as they could render in protecting exposures. The Army installation was located 1½ miles outside the city. Attempts to ventilate the building following closure of the doors were unsuccessful because of roof collapse (open wood-joisted framing with tar and gravel on wood plank covering). Lack of fire cut-off walls between the shops, warehouses and wing also influenced the rapid spread of the fire throughout the structure. Loss: Contents, $300,000; building, $100,000; total, $400,000.

March 7, New York, N. Y. Motorship:

Fire, originating at two points on the promenade deck, caused heavy damage to the superstructure of the 16,500-ton *John Ericsson* as it was berthed at a North River pier. Formerly the luxury liner *Kungsholm* of the Swedish-American Line, the vessel was built in 1938 at a cost of $4,600,000. During the war it carried more than 120,000 troops and traveled over 170,000 miles without incident. An official Coast Guard investigation revealed the origin of the fire to be in a concealed space over temporary wooden dormitories where electrical service wiring, heating conduits, and hot air vents were located. There was no evidence, however, that the fire was of electrical origin. Because of the simultaneous outbreak in two locations, it is regarded as suspicious in nature. There was a considerable delay in reporting the fire to the

New York Fire Department, perhaps as long as 25 minutes, and during the intervening time ship personnel attempted to control the fire with hand extinguishers and standpipe hose lines. When the alarm was transmitted, response was normal for a 4-alarm fire and first units reached the scene in 90 seconds. Eventually, a total of 38 pieces of land apparatus was working on the fire, with 3 Coast Guard fireboats. All except one pumping unit took suction (13 ft.), resulting in a minimum number of hose stretches on the pier. One pumper connected the high pressure city hydrant water supply system to the pier's standpipe. A serious list was corrected when firemen of the rescue squad were able to spill tons of water overboard by burning holes in the bulwarks on the promenade deck. Control over the blaze was secured in 3 hours, and the *Queen Elizabeth,* berthed on the opposite side of the same pier, escaped damage. Estimated loss, figured as to reconstruction costs, $500,000-$775,000. It is doubtful, however, that the ship will be used again for transoceanic service. The loss was not covered by insurance.

March 7, Clarksville, Tenn. Tobacco Warehouse:

A 2-story, mixed brick and frame, ironclad warehouse, built 50 years ago, burned to the ground, causing a tobacco loss of $328,900. Several familiar elements were again apparent: (1) light construction; (2) unprotected horizontal and vertical openings; (3) highly combustible contents (700 hogsheads of dark-fired tobacco); (4) lack of automatic sprinklers; (5) no watchman service (plant not in operation at time of the fire, 8:30 P.M.); and (6) delayed discovery by an outsider. The fire department could do little on receiving the alarm despite utilization of all its resources. Seven 2½-in. hose streams were used, mostly to protect exposures, including another large area, frame tobacco warehouse located 50 ft. distant. Perhaps the fact that the structure had a clear record for 50 years lulled the owners into unwarranted complacency regarding the fire danger. Loss: Building, $35,000; contents, $328,900; total, $363,900 (97 per cent covered by insurance).

March 9, Blackwell, Okla. Natural Gas Booster Plant:

Three persons were killed and extensive property damage was incurred by an explosion and fire at the Cities Service plant when the header of a 26-in. natural gas main failed at 7:53 P.M. There were 2 distinct blasts; the first when gas from the broken header came in contact with heated machinery in the engine room and the second which flashed unignited vapors which had permeated the area. The cooling tower, used to cool the gas as it came from the compressor, was destroyed by the heat and flame. The engine room and compressor building were heavily damaged. The office was completely leveled. Flames ignited grass over a wide area. Terrific heat and fire prevented access to the area until the numerous gas valves around the plant and on the two 26-in. inlet lines could be shut off. Local fire fighters then used one hose line from the single hydrant available (on a 3-in. dead end pipe 1½ miles long) and booster tank supplies until they could reach a water basin near the cooling tower to secure suction supplies. An appreciation of the force of the explosion may be gained from the fact that a crater 15 ft. deep and 30 sq. ft. in area resulted and a 30-ft. section of the 26-in. pipe totally disintegrated. Loss is set by company officials at $1,000,000. Interruption to customers serviced by the 3 relay lines from this booster station was slight, as hasty measures were taken to bypass the facility.

Three were killed and an estimated property damage of $1,000,000 resulted from an explosion and fire in a natural gas booster plant at Blackwell, Okla.

March 9, York, Pa. Hotel:

Fire, originating, as so many hotel fires do, in a guest room, caused heavy damage to the 7-story, unsprinklered Colonial Hotel. Believed caused by a cigarette, smoke was first discovered at 2:55 A.M. by persons on the street, issuing from a window on the fourth floor. Almost immediately flames burst from the window. Police turned in a box alarm and notified the manager. The hotel's fire alarm system was immediately sounded and the 20 hotel employees on duty executed their fire drill procedures

with calm efficiency. This, plus the fact that the stairwell was enclosed, with openings protected by standard fire doors, permitted 174 guests to escape to the street. The fire damage to the upper floors was serious, however. Light interior construction (wood lath on ordinary wood joist) and lack of fire stops in the concealed wall spaces permitted the flames to progress vertically. Guest room doors were also of light wood construction, presenting no barrier to the horizontal spread. Firemen responded promptly to the alarm and mutual aid facilities were promptly mobilized according to prearranged county-wide plans. Eight fire companies from surrounding communities responded to the call for assistance, while others moved into vacated stations. Interior standpipes were used by firemen, with 1½-in. hose lines as well as major streams from adequate public water supplies and hydrants. A total of 15 pumpers was employed plus an aerial ladder truck. Control was established by 5:30 A.M. Loss estimate according to preliminary figures is set at $250,000.

March 9, Danville, Va. Mercantile and Warehouse:

Chief John C. Long of the Danville Fire Department stated in his report of this fire that "any time a tobacco warehouse with so much floor space and not provided with automatic sprinklers is involved in fire, no fire department is going to extinguish it successfully." He added that they had lost 3 such plants in the last 17 years. The property involved in this case was a one and 2-story structure occupied by a group of mercantiles (including 2 auto supply stores, a transfer company, a grocery, and a dry goods store) with a tobacco warehouse on the second floor. The construction was chiefly ordinary brick wood-joisted type except that the wood roof had approximately 100 skylights and was supported by unprotected steel framework. When the alarm was feceived at 12:47 A.M. from a passing police officer, the flames had fully involved one of the first floor auto

Hotel employees well trained in fire drill procedures, plus an enclosed stairwell with openings protected by standard fire doors, permitted 174 guests to escape in this hotel fire in York, Pa. Estimated loss: $250,000.

Acme.

Lack of automatic protection or fire division walls permitted flames to sweep through the 50,000-sq.-ft. floor area of this Danville, Va., warehouse. Loss: $345,000.

supply stores which occupied 1500 sq. ft. of space. When firemen reached the scene they could not enter the structure and fought the fire from outside, using large hose lines. The tobacco warehouse occupied an unbroken 50,000 sq. ft. of floor space without any fire division walls to afford a fire break. The building was destroyed, although firemen did succeed in saving exposures. Losses were divided: $113,000 on building; $50,000 on tobacco; $182,000 on contents of other mercantile stores; total, $345,000.

March 11, Eastview, Ont. Plastic and Chemical Plant:

The large, one-story plant of Plastics and Chemicals, Ltd., was leveled by a fire which originated in a 350-hp motor in the mill room and spread throughout the structure with such rapidity that fire fighters were limited to outside hose streams. The fire, discovered by an employee at 3:30 P.M., occurred while the plant was in operation. The alarm was somewhat delayed, however, because employees attempted to extinguish the electrical fire with water and because the flames cut off the use of the plant's telephone, making it necessary to give the alarm from an adjacent plant. Lack of fire cutoffs, except at the paint room and laboratory, influenced the spread, but the exceedingly swift development of the fire was chiefly caused by the highly flammable nature of the contents and an explosion which lifted the roof. Production products of the plant consisted of plastic sheeting, composition flooring and paint. Work was proceeding on three 8-hour shifts when the fire destroyed the plant. Fire equipment at the scene included local apparatus, with volunteer crews and mutual aid units from Ottawa and Gloucester. Water supplies were adequate from hydrants 300 ft. and 600 ft. distant, but only one major hose line was placed in service, while three 1½-in. lines were used to protect exposures. Loss: $350,000, with insurance covering approximately 83 per cent.

March 12, Rockford, Ill. Warehouse and Manufacturing:

Ten concerns sharing a block-long plant (originally occupied by a single manufacturer) were wiped out by a fire which originated in the tire storage and repair room of a truck terminal and warehouse company. The structure was part frame, brick veneer, part ordinary brick, wood joisted, with a single source dry pipe sprinkler system in the main building where the fire started. The partial sprinkler coverage was installed in 1903, adhering to the 1896 pipe schedule (415 heads and 480 heads on each of 2 dry valves, no accelerators, and a

An obsolete sprinkler system, providing only partial coverage and lacking fire department connections, proved woefully inadequate in a fire of March 12 which swept a block-long plant in Rockford, Ill. The water supply, depending on a single public source, was substantially reduced on the day of the fire as the nearest well was out of service. Delayed alarm and construction weaknesses also contributed to the $950,000 loss.

maximum of 6 heads on a branch line), and lacked fire department connections. The water supply, a 6-in. connection off an 8-in. dead-end main, depended on a single public source. On the day of the fire this public source was substantially reduced as the nearest well (one mile distant) was out of service. An employee first discovered flames issuing from second floor windows at 5:20 P.M. An immediate telephone alarm brought 4 pumpers and one ladder truck, somewhat delayed by heavy traffic. The first crew to arrive had only 3 men and could make no effort to take a line inside the building until other equipment arrived. This delayed attempt to reach the origin of the flames was frustrated by minor explosions and severe flashes of flames. Interior sprinklers which operated properly were increasingly ineffective as fire department hose streams utilizing hydrants in the area were used. Hose streams were the maximum firemen could secure and pressure dropped to 10 lbs. and then to zero during early efforts to control the fire. A 54,000-gal. reservoir on an adjoining property was brought into service but was pumped dry in 3 hours of concentrated fire fighting. Construction weaknesses played a major part in the property loss. The light wood-joisted main building and 2 other adjoining portions (90 ft. by 50 ft., and 75 ft. by 135 ft.) added quick-burning fuel to the flames. Unprotected window openings contributed to the spread from the main section. Unprotected openings in an 8-in. fire wall on each floor were another deficiency responsible for fire spread. The exact cause of the fire remains undetermined. The only employees on the second floor left 50 minutes before the fire was observed, and there was no vulcanizing during the day. On previous inspections housekeeping had been good, and gasoline supplies were stored in standard safety cans. Occupancies sustaining major losses included the motor freight transfer warehouse, occupants of a general storage warehouse facility, and a woodworking plant making radio cabinets. Losses: Contents, $734,000; buildings, $214,000; exposures, $2,000; total, $950,000.

March 16, Clarksdale, Miss. Hotel:

An incendiary fire in the Alcazar Hotel Annex spread to cause heavy damage to the adjoining 4-story fire-resistive main hotel building. The happy fact that the fire occurred at 12:30 P.M., when the structure was relatively empty, prevented any loss of life. The salient features of the loss indicate how basic failures of construction influence fire spread, to wit:

1. The fire was set by a bell hop in a small room (12 ft. by 20 ft.) on the first floor of the Annex.

2. A maid first discovered smoke in an adjoining linen room, and it was apparent that the horizontal spread was through a 2½-ft. concealed space above the false ceiling of the first floor. This ceiling had been added to hide piping.

3. The wood-joisted interior construction (brick exterior walls) was easy prey to the flames, and the building, 14,000-sq.-ft. ground floor area, was without fire division walls.

4. Spread to the adjacent fire-resistive hotel was through a connecting passageway at the second floor level, which lacked an approved fire door at either end.

5. Flames traveled vertically through the main fire-resistive building via an open stairway and an improperly enclosed (wood doors) elevator shaft. The second, third and fourth floors were thus involved.

6. At each floor level, horizontal spread was influenced by wood doors and transoms to guest rooms which had been left open or burned through.

The fire department responded after a telephone call from the manager advised them that they were to "stand by while he investigated." When equipment reached the scene, the officer in charge immediately sounded a general alarm. Efforts to confine the blaze to the annex were unsuccessful despite a determined stand at the communicating passageway. The fire was brought under control about 2:30 P.M., but

Acme.

Clarksdale, Miss., March 16. A noontime incendiary fire caused heavy damage to the Hotel Alcazar and adjoining mercantile.

overhauling continued until 8:00. Damage was severe to the annex and to mercantile occupancies on the first floor of this building. Contents loss in the main hotel will run about 45 per cent. Falling walls and water damage were also sustained by another mercantile building adjoining the annex. Total loss is estimated between $350,000 and $600,000.

March 25, Centralia, Ill. Coal Mine Explosion:

The appalling mine disaster at Centralia, which resulted in the death of 111 men (65 were killed by burns and violence and 46 by afterdamp), was another manifestation of the death-dealing power of explosive dusts. Official investigators of the U. S. Bureau of Mines attribute the explosion to coal dust which was raised into the air and ignited by explosives fired in a dangerous and nonpermissible manner. The mine was extremely dry throughout and rock dusting (a recognized treatment to offset the dust explosion hazard) had not been done in the rooms or within 500 ft. of the faces of the working entries. The mine is opened by 2 wood-lined shafts, the main shaft through which employees, coal, and supplies are handled being 540 ft. in depth. The second shaft, a double-compartment down-cast air shaft, is 537 ft. in depth and 1200 ft. from the hoisting shaft. Four of the 6 working sections of the mine were affected by the violence of the explosion, while the 2 remaining sections were affected only by the afterdamp resulting from the combustion of the coal dust. It was conclusively determined by investigators that the presence of rock dust in entries, although somewhat deficient in quantity, prevented the further spread of the explosion throughout the mine and to the shaft bottom, and undoubtedly saved the lives of 31 of those in the mine. The explosion occurred at approximately 3:26 P.M., about 4 minutes before the end of one shift, when all face operations had ceased except the igniting of shots which had been charged earlier. While permissible explosive cartridges were used, the shots were fired with blasting caps and wax fuses ignited with the flame of carbide lamps and stemmed with coal dust in paper bags. Electric detonators should have been used for blasting the cartridges and only noncombustible materials used for stemming purposes. No evidence was found that methane gas contributed to the explosion. Thus, dust conditions alone presented the ignition hazard. Workmen's compensation insurance loss is estimated at $500,000. Subsurface property damage was heavy in affected sections, and considerable production delays resulted before rehabilitation could be accomplished and compliance secured with federal safety laws.

Acme.

Originally a stable, this substandard building, used by the Chicago National Bank, was gutted by fire on March 31. Only the bank vault remained intact. Loss: $250,000.

March 31, Chicago, Ill. Bank:

Bank fires are rare because construction is normally superior and hazards are guarded against. When substandard buildings are used, however, banks are no better protected from fire than structures of much higher inherent hazard. A case in point is shown in this report of a loss sustained by the Central National Bank in Chicago. The building, originally built as a stable, was in its remodeled form a substantial-looking structure of 2 stories and basement, with brick and stone exterior facing. The interior framing was wood, however, as were the floors and roof. Hidden from casual view were the concealed spaces formed by the false walls and ceilings, spaces which provided channels for the fire which started in the basement about 2:17 A.M. Discovery of the fire was made by a watchman on duty, but considerable delay in fire department response resulted when he became excited, ran from the building, hailed a passing cab and traveled half a mile, passing four fire alarm boxes, to report the fire personally at the nearest station. The building was

gutted while firemen poured water on the inferno with 15 hose lines and 6 turret streams. Only the fire-resistive bank vault was undamaged. When this vault was opened 5 days later, the contents were found intact and unaffected by either heat or water. Loss: $250,000.

April 1, Timmins, Ont. Hardware Warehouse:

A total loss resulted when fire of unknown cause broke out in the George Taylor Hardware Company warehouse at 1:40 A.M. Discovered by police on patrol, it was evident that the fire had a considerable start. This factor, plus the highly flammable nature of the contents, the frame building construction, the open elevator shaft to the second floor and the lack of automatic protection facilities, made fire suppression efforts a tragically delayed formality. Oil in drums, paints, furniture, tools, sporting goods, china, dynamite and auto supplies were concentrated in the 90 ft. by 100 ft. structure. The only favorable factors were a comparatively light wind and the opportunity of removing 3 box cars before they were destroyed. Firemen used nine 2½-in. hose streams in successful efforts to protect exposures. Loss: Building and fixtures, $100,000; contents, $400,000; total, $500,000. Insurance on contents aggregated more than $1,500,000, indicating the extent of the values in the unprotected, lightly constructed warehouse.

April 4, Coshocton, Ohio. Foundry:

While the loss by fire at the James W. Clow and Sons Foundry was large, it would have been considerably worse had not plant personnel and the public fire department exhibited knowledge and skill in confining the blaze to the building of origin. The stop made was particularly significant since it was accomplished at a division wall which could only partially qualify as standard. This wall was brick for 13 ft., with hard wood siding on wood studs above the brick to the roof line (no parapet), and had 4 large openings equipped with wooden sliding doors. In addition, the roof covering of both buildings was plank-on-timber, supported by open steel framework, with 4-ply built-up smooth surface roof covering. Application of hose streams continuously along this wall and roof was obviously the only saving factor, for total destruction of the first building involved resulted from the rapid spread of flames throughout the 18,000-sq. ft. structure. Deep charring of the wood members in the division wall indicated the seriousness of the fire threat. Another feature which indicated good fire-fighting technique was the saving of a second exposed building. One wooden window frame was burned in this adjacent structure, but the damage was limited to this small area. Good fire discipline was exhibited by the plant personnel. The alarm was given promptly to the public department

Daily Press.

Delayed discovery, flammable contents, frame construction, and lack of automatic sprinkler protection made manual fire fighting futile in this Timmins, Ont., warehouse fire on April 1. Loss: $500,000.

and to all personnel on duty during the night shift (outbreak occurred at 1:45 A.M.). Hose lines were laid from yard hydrants and placed in service before the town's pumper arrived. In the meantime the plant's fire pump was started, and electric power to the affected buildings cut off. By 6:00 A.M. the fire was practically extinguished. While it is obvious that automatic sprinkler protection might well have controlled the fire at its incipiency, lacking this means, the loss was held to a minimum. The cause is believed to have been the overheating of combustible wallboard where a 3-in. pipe vent from a gas-stream radiator passed through the wall in the office section. High contents values in machinery were largely responsible for the amount of the loss, estimated at $400,000.

April 13, Harrison, N. J. Gas Generator Building:

Failure of an employee to close the valve to a hot oil line during routine maintenance of a coke gas generator caused ignition of the oil vapors by the hot coals in the generator fire box. The oil could not be immediately cut off at the pump, and flames traveled through floor openings and around steel columns to the 95-ft.-high peak roof and then spread the entire 313-ft. length of the 3-story, chiefly brick, steel-joisted building. Adjoining this structure, a tower of equal height communicated through an unprotected opening. Flames entered this building and then spread down 100 ft. of a coke conveyor which was constructed of asphalt asbestos-protected metal, with a concrete floor supported by exposed steel columns and frames from the ground level to the top of the tower. The well-organized plant fire brigade of the Public Service Electric and Gas Company could not handle the situation, and an alarm was immediately turned in from a public box at the entrance to the property. Following prearrangements for a box alarm from this area, the fire equipment responding was automatically a major assignment, with assistance from Kearny and Newark. After it was determined that the oil supply had been cut off (approximately 10-15 minutes following the outbreak) and that there was no explosion danger, exterior application of hose lines through windows and from water towers was augmented by using interior lines stretched from numerous private hydrants. Complete extinguishment was secured within 4 hours, although the fire department was called back about 3:00 A.M. the following morning, 11 hours after the original fire, to extinguish a small roof fire. Important features concerning the fire pointed out by W. W. Wise of the Eastern Inspection Bureau include the following: (1) experience in this type of occupancy has been good, and this fire was obviously an operational error: (2) the provision of a quick shutoff of hot oil pumped under high pressure from a remote source seems warranted; (3) steel framework held up reasonably well; (4) use of asphalt asbestos-protected metal should be discouraged in this type of property, as the binder melted, dripped and burned and the metal warped seriously; (5) communicating openings to main buildings and conveyors should be protected by self-closing doors or shutters; (6) conveyors and other coal handling buildings, should have automatic protection. The loss has not been determined with accuracy but is estimated at $500,000.

Harrison, N. J., gas generator building, April 13. Loss: $500,000.

April 18, Leeds, Iowa. Flour Mill:

It was no surprise that the frame, ironclad, unsprinklered flour mill of the International Milling Company was destroyed when fire started on the fifth (top) floor of the mill structure at 11:57 P.M. Unprotected floor openings at stairwells, chutes, spouts, and legs permitted the flames to surge through this dusty structure of light construction within minutes following the alarm. A communicating section to a similarly constructed warehouse, lacking fire doors at the fifth floor opening to the mill, similarly almost guaranteed the total loss of this warehouse. The power house, however, was essentially fire resistive. Its only weakness was a set of *unapproved* wired glass windows in a raised concrete roof section, within 15 feet of the mill and thus directly exposed to the heat and flames. The entire interior of the power house (contents classed noncombustible) was burned out, leaving only the 12-in. brick walls and concrete floor and roof. The roof

windows, the one compromise with fire-resistant construction, permitted the heavy fire loss in this structure.

Two companies responded to a box alarm, and 3 additional calls for aid were made in the next 35 minutes. The mill, located in a suburban district, was served only by a 6-in. loop main. Thus, efforts to use a turret gun with a 1½-in. tip had to be abandoned as insufficient water was available for the required hose lines plus this unit. Attempts to control a fire of such magnitude with such limited water supplies were almost automatically doomed to failure. Effective work to save 48 grain tanks adjoining a nearby elevator and 8 of 21 box cars on a railroad siding was about all that could be expected. The possibility of overheated bearings was the only clue to the cause of the fire. Losses were divided $300,000 on building and machinery; $200,000 on stock; total $500,000.

Press Association, Inc.

An early morning fire destroyed the 112-year-old First Presbyterian Church in New Brunswick, N. J., on May 10, with a loss of $350,000.

May 10, New Brunswick, N. J. Church:

At 4:00 A.M. a telephone employee reported a fire in the First Presbyterian Church directly across the street from the telephone building. As in the majority of such cases where discovery is made by an outsider, the fire, originating in the basement, had gained tremendous headway. Firemen found the whole front portion of the church in flames on arrival and immediate calls were made for all available local apparatus as well as for help from nearby Highland Park. The structure, built in 1835, had brick walls, but interior construction was ordinary wood joisted, with roof framing also of combustible materials. The intensity of the fire caused collapse of the front cornice following the roof failure, but no one was injured. A brick fire wall separating the old church from the newer church school and community house adjoining at the rear prevented fire from entering the latter at the first and second floors where openings were protected by fire doors. In the cockloft, however, a hole in the fire wall permitted flames to enter the attic of the community house and considerable damage resulted to the newer building. A department store which flanked the church was also damaged as fire leaped across an 8-ft. alley to enter the mercantile through ordinary glass windows with wooden frames. Seven pumpers were used, with eleven 2½-in. hose lines and 2 deck guns placed in service. The destruction was so great that the cause could not be determined. Loss: $350,000.

May 21, Eastport, Me. Group Fire:

Several waterfront industrial properties of frame construction were destroyed by a fire which originated in the rendering plant of the Mearl Corp. The Mearl building was 50 ft. by 80 ft., mainly one story in height, and stretched across harbor waters on wood pilings. The fire was first reported by a neighbor about 7:00 P.M. The delay in reporting the fire is difficult to explain, as the Mearl plant was in operation at the time. Lack of automatic protection in this plant, coupled with the light construction and highly flammable contents, causing several explosions, gave the fire tremendous impetus. An exposed dwelling and warehouse were quickly involved, followed by ignition of a frame, sprinklered sardine cannery which was only 22 ft. from the nearest burning building. The water supply for fire protection purposes was weak, with pressures and volume satisfactory for only about one hour of concentrated fire fighting. Large volume hose streams had to be reduced in size to secure adequate pressures. Water could not be drafted from the harbor during the first 2 hours because of the low tide (this region has a 20-ft. tide). The sprinklers not only lacked sufficient water, but exterior walls burned so rapidly that they were afforded little opportunity to function effectively. When a 6-in. riser broke at 9:00 P.M., the water supply to the sprinklers was cut off at the street connection. Wood shingle roofs and gutters on dwellings were easy targets for flying embers, but only a few were destroyed, as the majority of these small fires were controlled by householders. The providential arrival of a heavy rainfall aided in preventing a conflagration, and a favorable wind kept sparks from falling in the closely built business section. Loss is estimated at $300,000 for buildings and contents directly involved;

Although the waterfront rendering plant of the Mearl Corp., Eastport, Maine, was in operation at the time, a neighbor first reported this May 21 fire. Water supply for fire protection was weak, and although the plant was built out over the harbor on piling, no water could be drafted from this source during the first 2 hours of fire fighting because of the extremely low tide. Three other buildings were destroyed, with an estimated loss of $410,000.

$10,000 for damages to dwellings and other remote exposures; and a maximum of $100,000 business interruption loss; total, $410,000.

May 29, New York, N. Y. Aircraft:

One of the worst aircraft accidents in history from the viewpoint of fire deaths occurred when a scheduled United Air Lines DC-4 crashed on take-off at LaGuardia Field, killing 43 persons. Using the shortest runway on the field (3500 ft.), the four-engine transport, loaded in excess of federal standards, was not able to get off the ground as shifting winds worked to the disadvantage of the pilot. Realizing that the plane was not becoming airborne, the pilot made a vain effort to stop the forward motion by ground looping. The heavy ship struck a 15 ft. embankment at the edge of the field, bounced into the air across an express highway, and crashed in a swampy open field with fire developing instantaneously. The crash was anticipated before it occurred by a fireman on duty at the airport crash station (operated by the New York Fire Department). The alarm was given and equipment reached the scene in 50 seconds. The two major crash units (Army Class 155) were driven to within 25 ft. and 35 ft. of the crashed aircraft. Two deck guns on one of these trucks were placed in service during the approach, sweeping flames away from the tail section. Three hand fog lines covered rescue men as they entered the rear utility door (18 in. x 24 in.), through burned out portions of the fuselage, and through a forcible entry opening. Firemen removed nine occupants in the crucial moments, while the pilot escaped unassisted. (Press reports crediting a bystander for rescue work are inaccurate.) Five of those rescued died from burns in hospitals. The small crash units (two Army surplus Class 125) were employed to provide additional fog lines to protect rescue operations, while the fifth unit supplied foam for holding down heat and flame (2000 lbs. of dry powder used). A 2500-gallon water tank truck replenished the water supply to one of the Class 155 trucks. A trained crash crew of 11 men thus performed with maximum efficiency their intended function under the severe limitations imposed by the crash conditions immediately unfavorable to rescue opportunities. Chief handicaps, according to firemen, were: swampy terrain; 1300 gallons of burning gasoline plus flammable hydraulic fluid, oil, and alcohol; flaring of burning magnesium parts; ignition of synthetic leather upholstery; limited manpower and equipment (during initial stages); plus the fact that the aircraft was 75% involved at time of arrival. Preliminary reports indicate that all deaths were caused by burns and suffocation, none by impact injuries. In this respect especially, this accident differs from the accident the following day involving an Eastern Air Lines DC-4, where 53 persons were killed by impact and the resultant fire merely precluded any attempts to retrieve the bodies. Loss to aircraft: $450,000.

FIRE PREVENTION EXPERTS
recommend
CENTRAL STATION-SUPERVISED
FIRE DETECTING AND ALARM SYSTEMS

From report of South-Eastern Underwriters Association on Hotel Winecoff fire

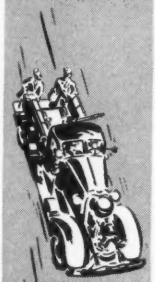
Where a modern, trained fire department exists, quick extinguishment of a fire may be expected if notification is given of the fire in its early stage. The installation of an approved *automatic* fire alarm system, transmitting an alarm to the fire department, *preferably through a central supervising company is desirable.*

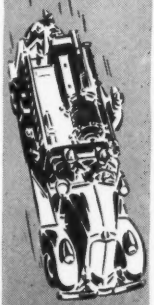
From report of Cook County Inspection Bureau on Hotel La Salle fire

The tragic results of this fire were brought about by the absence of means for fire detection and alarm. Every hotel should be provided with an approved alarm system. The prompt transmission of alarms to the fire department can best be secured *by means of Central Station Supervisory Service.*

From report of International Association of Fire Chiefs on fire protection for hotels

Requirements shall include frequent and regular inspection and test of all above mentioned systems. Proper supervision and maintenance of such protective systems are essential to reliable operation, and it shall be required that this procedure and the assurance of prompt transmission of alarms to the fire department can best be obtained by means of *Central Station Supervisory Service* wherever it is available.





Reports of fire protection experts who investigated the La Salle, Canfield and Winecoff hotel disasters point out that in all these fires the tragically fatal consequences were largely the result of belated discovery or delayed alarm, and stress the importance of fire detecting and alarm systems, *supervised and maintained through a central station agency.*

For hotels and all types of commercial and industrial properties, ADT provides Fire Protection Services including automatic and manual fire alarm systems, installed, supervised, inspected, tested and maintained through ADT Central Stations located in all principal cities of the United States. In more than 350 municipalities these systems are available with Central Station connection; elsewhere they are furnished as local or direct-to-fire department systems with ADT supervision, inspection, test and maintenance service.

Whatever the type of system, ADT provides the specialized attention required to assure proper and effective operation when an emergency arises.

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SPRINKLER SUPERVISORY AND WATERFLOW ALARM SERVICE
MANUAL FIRE ALARM SERVICE
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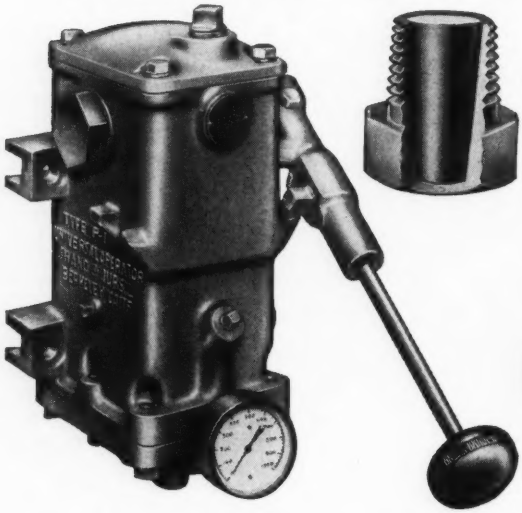

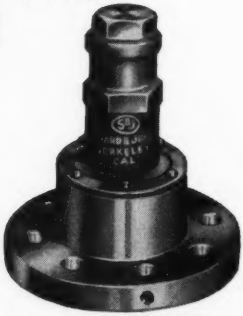

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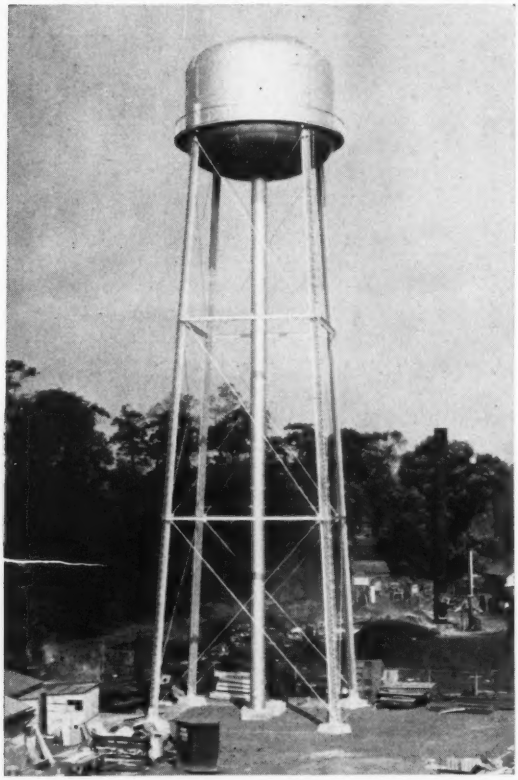

100,000-gal. elevated steel tank at General Motors plant in Tarrytown N.Y.

Elevated Steel Tanks Provide Gravity Pressure

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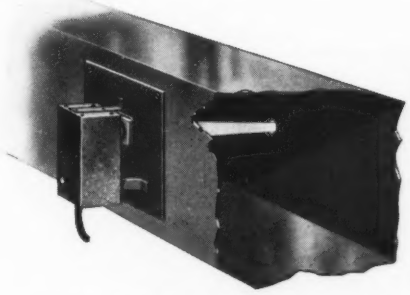

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The Light Source projects a light-beam across the ventilating duct to the Photo-Cell Receiver. When this light beam is intercepted by smoke of predetermined density, the ventilating fan is stopped automatically and warning is sounded! The stopping of the fan, or air flow, permits the natural functioning of ordinary thermally operated fire extinguishing equipment.

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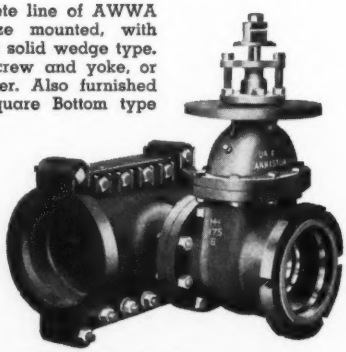

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M & H Tapping Sleeve and Valve (illustrated above) is used to tap a main under pressure for the purpose of taking off a branch leading to automatic sprinklers, fire hydrants, etc. By this method the cut-in is made without interrupting the services on the existing water main.

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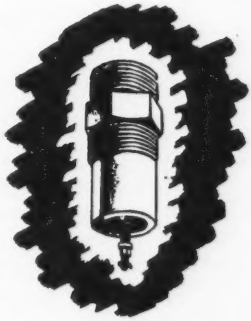

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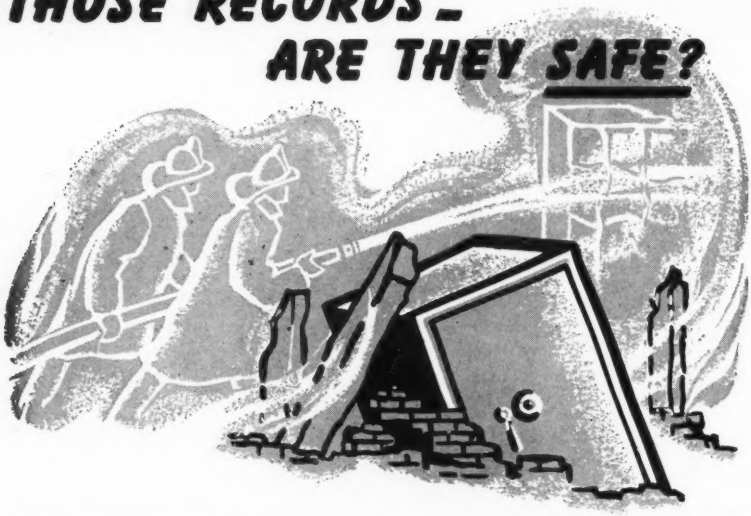
PIONEER AND LEADER IN THE DESIGN AND MANUFACTURE OF PRECISION EQUIPMENT FOR USING AND CONTROLLING LP GASES

THOSE RECORDS— ARE THEY SAFE?



VITAL BUSINESS RECORDS are needed not only to give evidence of the character and amount of the property destroyed; often the very ability of a business to go on after a fire depends on them. They should be safely protected under even the most adverse fire conditions.

Thousands of case histories in the hands of the Underwriters' Laboratories, Inc., The National Fire Protection Association, and the Safe Manufacturers' National Association indicate that all safes made prior to 1917 as well as many unlabeled safes made since that time are obsolete in construction, untrustworthy and deficient in fire-resistance qualities according to present-day knowledge and testing standards and, therefore, of uncertain protective value.

It is also the considered opinion of this Association that uninsulated steel plate-type, vault or safe doors with or without inner doors should not be used for the protection of valuable records, documents or merchandise.

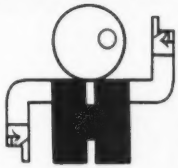
The undersigned members of this Association have availed themselves of the improved standards that have been developed and pledge themselves to a strict observance thereof.

SAFE MANUFACTURERS' NATIONAL ASSOCIATION
366 MADISON AVENUE, NEW YORK 17, N. Y.

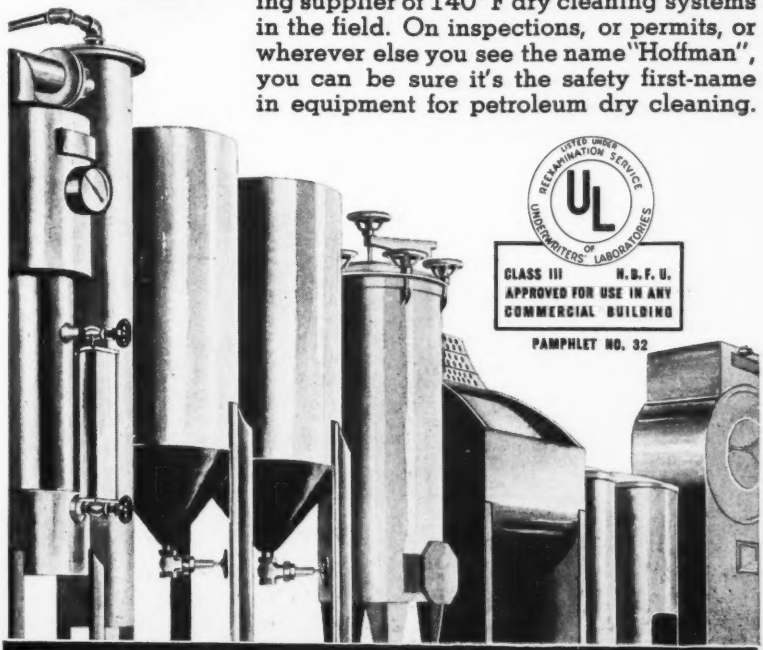
DIEBOLD INCORPORATED, Canton, O.
HERRING-HALL-MARVIN SAFE CO., Hamilton, O.
MEILINK STEEL SAFE COMPANY, Toledo, O.
THE MOSLER SAFE COMPANY, Hamilton, O.
PROTECTALL MANUFACTURING CORP., Syracuse, N. Y.
REMINGTON RAND, INC., Marietta, O.
THE SHAW-WALKER COMPANY, Muskegon, Mich.
THE VICTOR SAFE & EQUIPMENT CO., No. Tonawanda, N. Y.
YORK SAFE & LOCK COMPANY (Division of Diebold Incorporated), York, Pa.

PROVED by a 12-Year CLEAR LOSS RECORD

HOFFMAN 140-F UNITS FOR SAFE DRY CLEANING



Year after year, the safety of commercial dry cleaning with 140° flash-point, petroleum solvent has been proved by Hoffman equipment. Hoffman originated the process in 1935 and, ever since, has been the leading supplier of 140° F dry cleaning systems in the field. On inspections, or permits, or wherever else you see the name "Hoffman", you can be sure it's the safety first-name in equipment for petroleum dry cleaning.



LISTED UNDER RE-EXAMINATION SERVICE — UL — UNDERWRITERS' LABORATORIES

CLASS III N.B.F.U.
APPROVED FOR USE IN ANY COMMERCIAL BUILDING

PAMPHLET NO. 32

U. S. HOFFMAN MACHINERY CORPORATION
105 Fourth Ave., New York 3, N.Y.

DRY CLEANING, LAUNDRY & GARMENT PRESSING EQUIPMENT

What's DIFFERENT about Globe Protection

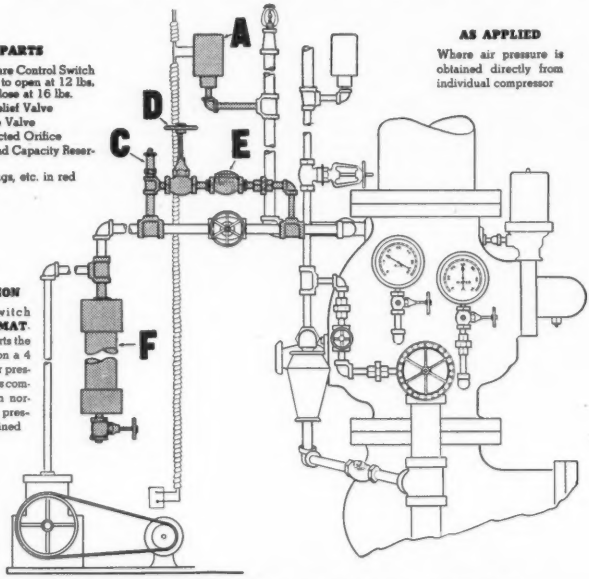
AUTOMATIC AIR PRESSURE MAINTENANCE FOR DRY PIPE SYSTEMS

PARTS

A—Pressure Control Switch —Set to open at 12 lbs. and close at 16 lbs.
C—Air Relief Valve
D—Globe Valve
E—Restricted Orifice
F—Oil and Capacity Reservoir
Also Fittings, etc. in red

AS APPLIED

Where air pressure is obtained directly from individual compressor



OPERATION

Control Switch "A" **AUTOMATICALLY** starts the compressor on a 4 lb drop of air pressure and stops compressor when normal system pressure is regained

POSITIVE POLICING FOR DRY PIPE SYSTEMS

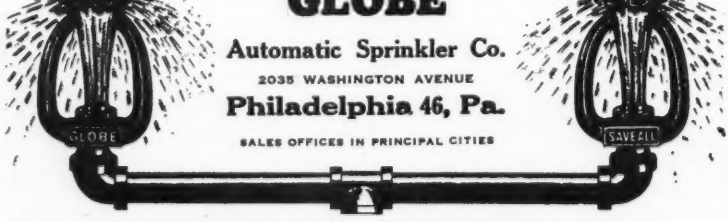
GLOBE

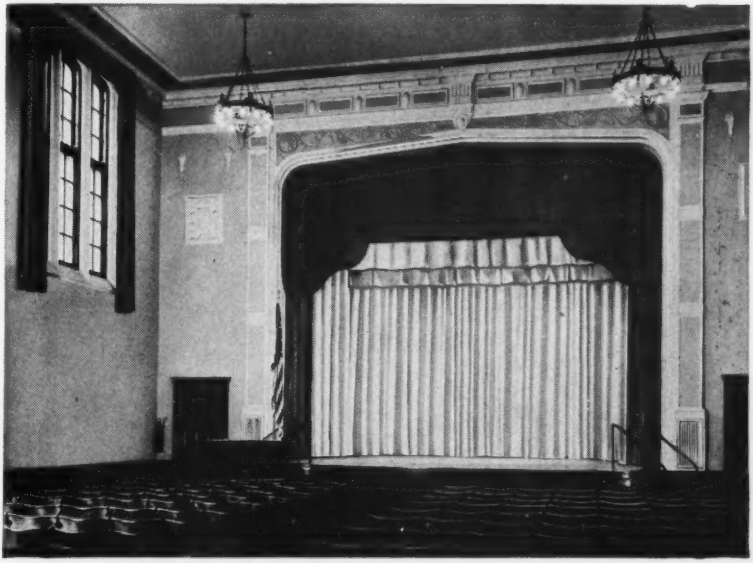
Automatic Sprinkler Co.

2035 WASHINGTON AVENUE

Philadelphia 46, Pa.

SALES OFFICES IN PRINCIPAL CITIES





AUDIENCE SAFETY demands fabrics that *CANNOT BURN*

A theatre fire is too horrible a disaster to take unnecessary chances. The flameproofing of combustible fabrics may lead to a false sense of security—for the fire-resistance of chemically-treated organic fabrics depends upon the type of chemical used, and the length of time since the last treatment.

That is why more and more theatres, schools and public auditoriums are being redecorated with Fiberglas*—the decorative fabrics *woven entirely of finely spun, inorganic glass* filaments. Fiberglas fabrics are not merely flameproof—but *fireproof.* They cannot burn; and, unlike organic fabrics, will not emit asphyxiating smoke and fumes if exposed to flame.

HALE SCHOOL
in Chicago

The auditorium installation shown above combines two Fiberglas* fabrics: Tuscan Gold back drop, legs and borders—Jade diamond weave front curtain. This dignified stage and window treatment is easily cleaned. Fiberglas fabrics are endorsed by all public safety officials. Theatre installations often include wall coverings of Fiberglas to assure maximum fire-safety.

Fiberglas fabrics are *permanently* non-combustible; immune to rot or decay, always operate at 100% efficiency. Will not smolder or propagate flame; minimize the hazard of suffocation from oxygen depletion in the event of fire in enclosed places.

WRITE FOR SAMPLES AND INFORMATION

THORTEL
FIREPROOF FABRICS

FIBERGLAS Listed by Underwriters' Laboratories, Inc. as "Non-Combustible Fabric;" approved by the Bureau of Standards and Appeals, City of New York.*

ARCHITECTS BUILDING, 101 PARK AVENUE, NEW YORK 17, N. Y. • LEXINGTON 2-0711

Sales representatives or recommended workrooms in: **BOSTON, BUFFALO, CHICAGO, CINCINNATI, CLEVELAND, DENVER, DETROIT, LOS ANGELES, NEW ORLEANS, OAKLAND, PHILADELPHIA, PITTSBURGH, RICHMOND, SAN FRANCISCO, ST. LOUIS, TOLEDO, WASHINGTON**

*T.M. Reg. U. S. Pat. Off. Owens-Corning Fiberglas Corp.

Original Woodcut by Lynd Ward

Centuries of service have established the long life and low maintenance cost characteristics of cast iron pipe. The science and art of making pipe has progressed steadily over these hundreds of years. We would welcome those who specify, buy, or use cast iron pipe, who wish to visit our plants and research laboratory to witness our current manufacturing process and controls. These modern methods result in a finer, more uniform pipe, either pit cast or centrifugally cast.

U.S.
cast iron
PIPE

U. S. PIPE & FOUNDRY CO.
General Offices: Burlington, N. J.
Plants and Sales Offices throughout U.S.A.

Protect these important items with Pyrene!

Take another look at your balance sheet. Fire can play havoc with it. Naturally, Pyrene* Fire Equipment *can't* give you any protection for your cash in bank, but it *can* stop fire from destroying your records of accounts receivable and two of your most important physical assets, your ***buildings and equipment and inventory.*** And it *can* protect you from loss of profits due to production stoppage.

Pyrene extinguishers at strategic spots in your plant put out fires before they spread and cause real damage. There is a specific type of Pyrene extinguisher for every location and hazard:

For Class A Fires—ordinary combustibles such as wood, paper, textiles and trash. The Pyrene Soda-Acid Extinguisher is recommended for use in offices, stores, warehouses and corridors. Also Cartridge Operated and Pump Tank types.

For Class B Fires—gasoline, oil, paint, solvents and other flammable liquids. The Pyrene Foam Extinguisher produces 22 gallons of fire-smothering foam. Covers flammable liquids with a tough, air-tight layer of tiny bubbles. Also Vaporizing Liquid type.

For Class C Fires—electric motors, transformers, generators. Pyrene Vaporizing Liquid Extinguishers are especially suited for these fires because they are non-conducting, non-damaging. Available in 1 qt. and 1½ qt., Pump Type; 2 qt. and 1 gal. Stored Pressure Type (which requires no pumping).

Pyrene Manufacturing Company

Newark 8, New Jersey

Affiliated with C-O-Two Fire Equipment Co.

T.M. Reg. U.S. Pat. Off.

★ 1921 ★ 1947 ★

26 YEARS OF SUPERIOR SERVICE

Prove

Your BEST PROTECTION against the fury of FIRE is a

CENTRAL AUTOMATIC SPRINKLER SYSTEM

Whether it be a wet pipe system or a dry pipe system — or perhaps a Central "Electro-Speed" Deluge Sprinkler System, you will find the one BEST TYPE is a CENTRAL SPRINKLER SYSTEM.

They pay for themselves in insurance savings.

Write us for information.

CENTRAL AUTOMATIC SPRINKLER CO.

Main Office and Factory: Cannon Avenue at Fourth Street

LANSDALE, PENNA.

(Representatives in principal cities in United States, Canada and Foreign Countries)

"Central Sprinklers answer the burning question"

★ 1921 ★ 1947 ★

NATIONAL

AER-O-FOAM AND NOZZLES

. . . simple, dependable Fire Protection

Aer-O-Foam is simple to apply . . . clings to vertical surfaces.

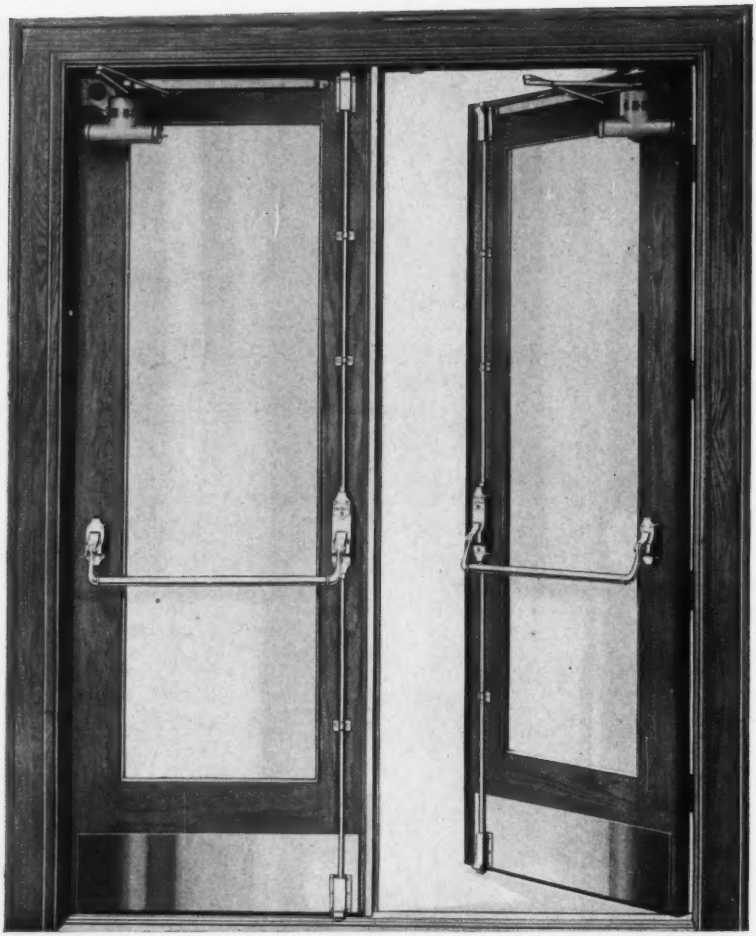
NATIONAL Aer-O-Foam and Nozzles form an effective combination for stopping flammable liquid fires. Aer-O-Foam flows quickly, forming a tough, lasting blanket that smothers oil fires . . . insulates threatened areas . . . prevents flashbacks. It is *non-corrosive.*

NATIONAL "RP" Type Nozzles, provided with pick-up tubes, are easily handled by one man. These Nozzles deliver a spot pattern stream with no weeping . . . are machined for spray attachment. TELL US YOUR fire problems . . . we will recommend specific protective measures.

NATIONAL FOAM SYSTEM, INC.

Specializing in Foam Fire Protection

Packard Building, Philadelphia 2, Pa.



Von Duprin

TRADE MARK REG.

SELF-RELEASING FIRE AND PANIC EXIT DEVICES

Always Assure Safe, Quick, Easy Exit.

VON DUPRIN DIVISION

VONNEGUT HARDWARE CO., INDIANAPOLIS 9, INDIANA

In Canada, write Yale & Towne Mfg. Co. (Canadian Div.), St. Catharines, Ont.

...Puts out Fires Faster with Less Water!

Half the weight of the famous Rockwood all-purpose nozzle, the new LIGHTweight special aluminum-alloy type SG-48 WaterFOG Nozzle will give you three types of discharge — one to fit every need for providing all-around fire protection.

Easy to install and operate, this amazing new improved Rockwood WaterFOG Nozzle will permit your firemen to reach the very root of the fire and to attack it without physical punishment. It will also provide them with greater protection from fire, smoke and fumes.

A simple movement of the control handle will bring the correct type of discharge to control or put out fires in both ordinary combustibles and flammable liquids.

The SG-48 WaterFOG Nozzle is recommended for use in municipal fire departments, industrial plants, chemical plants, mercantile and public buildings, oil refineries, etc.

Rockwood WaterFOG is also available in the form of fixed piping systems and are today protecting many types of equipment, processes and structures, transformers, paint shops, quench tanks, engine test cells, etc.

For more complete descriptive information, write for circular C-501R.

ROCKWOOD

ROCKWOOD SPRINKLER COMPANY

56 HARLOW STREET WORCESTER 5, MASSACHUSETTS

Specialists in Fire Protection Engineering, Equipment and Installation since 1907

Products of Fiberglas

LISTED AND UNDER RE-EXAMINATION SERVICE BY
UNDERWRITERS' LABORATORIES, INC.

★

"NONCOMBUSTIBLE FABRIC" (Retardant No. 2815)

Owens-Corning Fiberglas Corp., Manufacturer, Toledo, Ohio.

"Fiberglas" Type ECC fabrics woven from natural white color, 100% glass yarns with the fabrics having no after-weaving color coatings. For use as drapery. These fabrics do not burn or propagate flames.

"NONCOMBUSTIBLE FABRIC" (Retardant No. 2814)

Thortel Fireproof Fabrics, New York, N. Y.

"Thortel" fabrics woven from 100% glass yarns and finished with surface color. For use as drapery. These fabrics do not burn or propagate flames.

"UNIT AIR FILTERS FOR AIR CONDITIONING SYSTEMS" (Retardant No. 2423)

Owens-Corning Fiberglas Corp., Manufacturer, Toledo, Ohio.

Throw-away type filter units. Dust-Stop 1A and 2A (Dry Type), Class 1. Dust-Stop 1B and 2B, Class 2.

★

TESTS ON LABORATORIES' 1947 CALENDAR

- ..."DUST-STOP" AIR FILTERS.
- ...NON-METALLIC SHEATHED BUILDING CABLE and other electrical products embodying Fiberglas.
- ...FIBERGLAS THERMAL AND ACOUSTICAL INSULATING BOARDS.
- ...FIBERGLAS ROOFING MAT ... And Other Building Products.

OWENS-CORNING
FIBERGLAS

OWENS-CORNING FIBERGLAS CORPORATION
TOLEDO 1, OHIO

THE MASTER OF FLAME
ANSUL
FIRE EXTINGUISHING EQUIPMENT
duGas

DRY CHEMICAL
FIRE EXTINGUISHERS

New...

Faster Put-out by Inexperienced Operators

The difference between a small fire and a major disaster may be only a matter of seconds . . . WHEN THE FIRE STARTS.

An outstanding feature of the new Ansul-Dugas Extinguisher is its simple and quick operation. The new nozzle design makes expert extinguishing possible even by inexperienced persons.

HERE ARE OTHER IMPORTANT FEATURES

- 53% more Fire-Stopping Power.
- Highest Rating for SPEED and EFFECTIVENESS as determined by impartial authority.*
- Quicker, easier, on-the-spot recharge after use.
- Greater fire-fighting effectiveness — pound for pound, dollar for dollar.
- Larger range stream and greater shielding of heat from operator.
- Increased fire-fighting capacity without increased weight.
- Engineered to resist corrosion.

STOP FIRE FASTER!

with Ansul-Dugas Dry Chemical Extinguisher

*Write for charts based on authoritative data of comparative ratings as determined by a national approval agency.

ANSUL CHEMICAL COMPANY
FIRE EXTINGUISHER DIVISION, MARINETTE, WISCONSIN

C - O - TWO

snuffs blazing liquid fires

IN NEXT-TO-NOTHING FLAT

When fire starts in spray booths, dip tanks, mixing vats, drying ovens, solvent baths or volatile storage, even the shortest delay can prove costly. Stop fire with C-O-Two—fast, positive fire protection. C-O-Two blankets fire with clouds of dry, sub-zero carbon dioxide gas-and-snow, puts out fire without damage to expensive machinery. Non-conducting, it is recommended for burning electric equipment . . . will not corrode metal or ruin wiring. Leaves no after-fire mess.

C-O-Two fire equipment is available in a size and type to suit every hazard—Squeez-Grip portables, wheeled extinguishers, hose rack units, fixed pipe systems and automatic detecting and extinguishing systems. Let us help you protect your plant. Write for more information.

C-O-TWO

C-O-TWO FIRE EQUIPMENT COMPANY

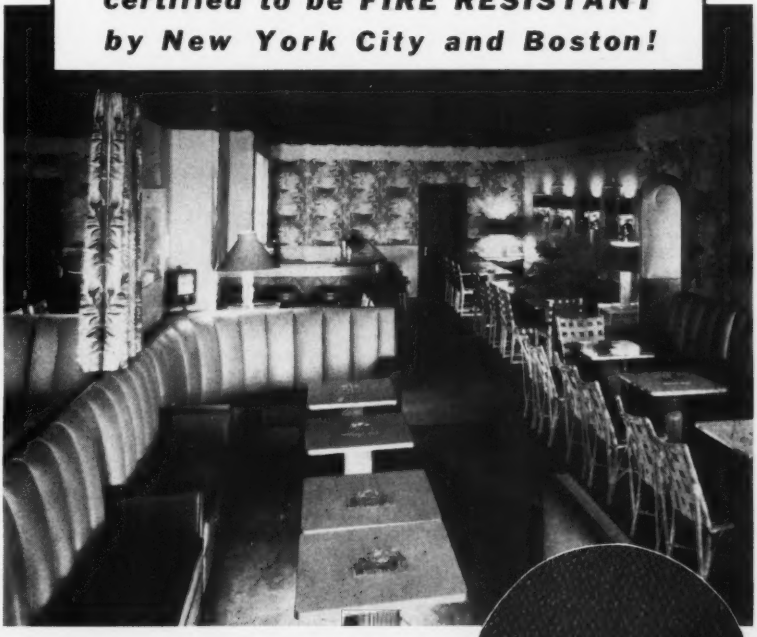
NEWARK 1 • NEW JERSEY

Sales and Service in the Principal Cities of United States and Canada

AFFILIATED WITH PYRENE MANUFACTURING COMPANY

TOLEX* UPHOLSTERY

certified to be FIRE RESISTANT by New York City and Boston!

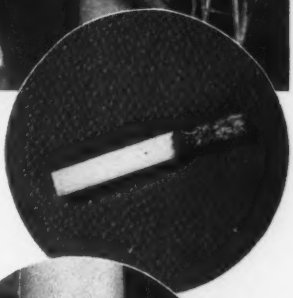


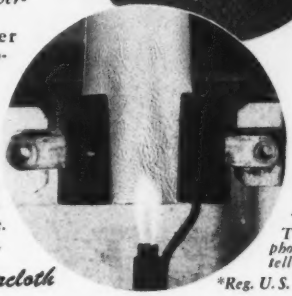
Among progressive cities, the trend is more and more toward flame-resistive requirements in furnishings for places of public gathering.

Today—New York City, Boston and other large cities have fire-resistant requirements for upholstery, wall coverings and interior decorations *which are met by TOLEX plastic leathercloth.*

TOLEX is a product of Textileather Corporation . . . pioneers in the development of fire-resistant upholstery leathercloth.

Consulting Service available to you!
We will gladly send our technical representative to discuss fire-resistant leathercloth specifications and test methods with fire marshals, fire departments, fire prevention boards or underwriters. There is no charge for this service. Write to Textileather Corp., Toledo, Ohio.





These TOLEX photographs tell the story

35 Years of Leadership in Leathercloth

*Reg. U. S. Pat. Off.

5 for 4

A New Addition to GENERAL'S

Line of ① -Snofoe Carbon Dioxide Extinguishers

GENERAL'S new 5-lb. ① -Snofoe carbon dioxide extinguisher costs no more than the 4-lb. size—yet gives you 25% more fire protection. This makes GENERAL ① -Snofoe the best buy in the fire extinguisher market—best for protection; best for economy.

The new 5-lb. GENERAL ① -Snofoe fits the standard 4-lb. wall bracket. Improved design of the shell makes it unusually light and easy to handle, with no sacrifice of structural strength.

IF IT'S GENERAL IT'S DEPENDABLE

New 2½-lb. Size, Also!

Another new ① -Snofoe—2½-lb. size—gives 25% more fire protection than the 2-lb. size, yet costs the same. It is light, strong, and easy to handle, due to improved shell design—an outstanding value. See the yellow section of your local telephone directory for your nearest GENERAL dealer. Ask him to show you both these new ① -Snofoe extinguishers, or write for complete details.

Service For You . . .

Through GENERAL'S Distribution System

To assure you immediate service, GENERAL maintains a nation-wide network of 20 branch offices and warehouses. There is one near you. Call your local GENERAL representative for advice and counsel on all your fire protection needs, or write direct.

THE GENERAL DETROIT CORP.

Manufacturers of Fire Extinguishers
Motor Fire Apparatus and Allied Equipment

2270 E. JEFFERSON • DETROIT 7, MICHIGAN

NEW YORK • PHILADELPHIA • ATLANTA • CHICAGO • DALLAS

West Coast Subsidiary: The General Pacific Corp.
Los Angeles San Francisco Denver Seattle

Distributors in Principal Cities

RELIABLE

AUTOMATIC SPRINKLER DEVICES

PROTECTING LIFE AND PROPERTY FOR OVER 25 YEARS

Reliable Automatic Sprinkler Devices have an excellent field record . . . superb in design and construction . . . are universally approved by all Fire Insurance and Governmental Authorities . . . and effect maximum reductions in fire insurance premiums.

They comprise a complete line including Automatic and Open Sprinklers, Alarm Valves, Dry Pipe Valves, Accelerators, Circuit Closers, Water Motors and all other accessories required in Sprinkler Systems.

Reliable Systems are protecting thousands of properties throughout the United States, Canada and foreign countries.

FURTHER INFORMATION UPON REQUEST

Manufactured and Distributed by

The Reliable Automatic Sprinkler Co. Inc.

BRONX STREET — MOUNT VERNON, N. Y.

like having a

FIRE DEPARTMENT

IN YOUR OWN PLANT

INDUSTRIAL SPRINKLER SYSTEMS

Viking Sprinkler Systems go into action with the speed of a Fire Department in your own plant. In peace and war Viking Sprinkler Systems are protecting industrial plants across the nation against the universal enemy of production . . . . FIRE. There is a Viking dealer near you to give you all the facts.

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THE VIKING CORPORATION
HASTINGS, MICHIGAN

YOUR GUARANTEE
OF A PERMANENT FIRE—WATER—
WEATHER—MILDEW-RESISTANT TREATMENT
"FIRE CHIEF FINISHED"
The patents, 2,299,612 and 2,044,176, developed and owned by Wm. E. Hooper & Sons Company, identify the PERMANENT fire, water, and weather resistant finish—for both outdoor and indoor uses. All goods finished at the Hooperwood Mills bear the trademark, "FIRE CHIEF" — your guarantee of quality.
As further guarantee, the UL label appears on every yard of FIRE CHIEF finished fabrics processed at the Hooperwood Mills. This label may identify the products of licensed finishers only after specific approval has been obtained from the Underwriters' Laboratories, Inc.
WM. E. HOOPER & SONS CO.
New York PHILADELPHIA Chicago
Mills: Woodberry • Baltimore, Md.
HOOPERWOOD
FIRE CHIEF
"Fire-Chief" Finished
U. S. Patent No. 2,299,612 and other patents
HOOPERWOOD COTTON DUCK

IF you're planning new construction or the remodeling of your existing facilities, adequate defense against fire must receive primary consideration. For the very structure of business enterprise is dependent upon continuity, and *fire can destroy that continuity with deliberate suddenness.*

Today's business executives are aware more than ever before of the wisdom of safeguarding lives and property. They, too, are quick to recognize the advantages of "Automatic" Sprinkler protection, industry's most effective weapon against fire . . . and this recognition did not come overnight. It is the result of more than half a century of pioneering and leadership in the design, engineering, and construction of approved fire extinguishing devices and systems which *must* and *do* meet the approval of all leading fire insurance bureaus.

Want further information on automatic sprinkler protection? Your telephone will quickly reach an "Automatic" Sprinkler Engineer located in the principal cities of North and South America, or write "Automatic" Sprinkler Corporation of America, Youngstown 1, Ohio.

FIRE PROTECTION

DEVELOPMENT ENGINEERING

Automatic Sprinkler

MANUFACTURE INSTALLATION

"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA
YOUNGSTOWN 1, OHIO
OFFICES IN PRINCIPAL CITIES OF NORTH and SOUTH AMERICA

"Automatic" Sprinkler devices and systems are listed by Underwriters' Laboratories, Inc., and approved by Factory Mutual Laboratories.

Eliminate

Delayed Alarms

Reduce

Fire Losses

WHEN FIRE OCCURS
Call the Fire Department. Delay creates unnecessary fire waste and life hazard

Fire Alarm Boxes
Save Time and Protect Life, Property and Income

Write for details

THE GAMEWELL COMPANY
Newton Upper Falls 64 - - Massachusetts

A Complete Package

A Grinnell System for protection against fire is a manufactured unit rather than an assembly of various parts from different sources.

The components for Grinnell Systems, with the exception of the pipe, are manufactured in Grinnell plants . . . under careful and expert supervision. Responsibility for the whole equipment is thus centralized. This is a factor of utmost importance to any prospective purchaser of a Grinnell System. Complete stocks carried at all plants eliminate delays and assure fast and uninterrupted installation.

Every type of Grinnell System for protection against fire is available through Grinnell. Each System is engineered to meet specific conditions. A Grinnell engineered installation can be made in every case without resort to makeshifts or untried adaptations. Complete information is available for the asking from any of our offices throughout the country. Grinnell Company, Inc., Executive Offices, Providence 1, Rhode Island.

GRINNELL SYSTEMS

Protection Against Fire